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CONTENTS.

	PAGE
Council and Officers	i–ii
Committees	ii–iv
General Notices :—	
Copyright	vii
Issue of Journal	vii
Changes of Address	vii
Papers and Articles	vii–viii
Binding of Journals	viii
Reprints of Papers	viii
Bibliography and Abstracts	viii
Medal for Student Members	viii
Advertisements	viii–ix
Appointments Register	ix
Library	ix–xi
Personal Notes and Special Notices	xi
Empire Motor Fuels Committee	xii
Sir John Cass Technical Institute	xii
The Industrial Fellowships of the Mellon Institute ..	xiii
International Petroleum Exposition and Congress ..	xiv

PAGE

Obituary Notices :—

Sir George Beilby, LL.D., F.R.S. .. .. .. xiv–xvi

G. E. Brown xvi

C. Percy Hale xvi

Reports on the Progress of Naphthology during 1923 :—

Heavy Distillates, by H. Moore, M.Sc. (Tech.), A.I.C., F.C.S... 607

Lubricants and Lubrication, by R. W. L. Clarke, B.Sc., F.I.C. 612

Special Products, by F. G. P. Remfry, B.A., B.Sc., A.I.C. 618

Chemistry, by F. B. Thole, D.Sc., F.I.C., F.C.S. .. 622

Analysis and Testing, by S. Bowman, F.I.C. .. 628

Cracking, by R. Pitkethly and A. E. Dunstan, D.Sc., F.I.C., F.C.S. 631

Refining and Refineries, by J. McConnell Sanders, F.I.C., F.C.S. 640

Agwi Refinery, by J. McConnell Sanders, F.I.C., F.C.S. 648

Skewen Refinery, by A. M. O'Brien, F.I.C., F.C.S. 650

Scottish Oil Industry 651

The Burmah Oil Company, by John Gillespie, M.I.Mech.E. 651

Oil Separators, by H. Barringer, M.Inst.C.E., M.I.Mech.E. 653

Petroleum Geology, by J. N. Montgomerie .. 655

Rumania, by C. Leu 661

Hydrogenation, by H. I. Waterman and J. N. J. Perquin 670

The Institution, by G. Sell 677

Statistics, by Arthur W. Eastlake, M.I.Min.E., A.M.I.Mech.E. 682

Bibliography 684

PAGE

Students' Section, London Branch :—

Fuller's Earth, by A. RAUCH, A.R.C.Sc., and G. E. PAIN, A.R.C.Sc. 687

Percussion Systems of Drilling, by H. G. AUSTIN.. 695

Mineral Resources of Western Canada: Bentonite or Colloidal Clay, by H. S. SPENCE 707

Bituminous Sands of Northern Alberta, by S. C. ELLS 710

The Constitution of Asphalt, by F. J. NELLENSTEYN.. Discussion, by J. E. HACKFORD 717

Reviews 720

Current Bibliography, compiled by W. J. WILSON, F.I.C., A.C.G.I. 195A

Abstracts, compiled by S. F. BIRCH, S. BOWMAN, F.I.C., J. E. MARSHALL HALL, A.R.S.M., H. MOORE, A.I.C., F.C.S., W. S. NORRIS, F. G. P. REMFRY, B.A., D.Sc., A.I.C., G. SELL, T. A. SMITH, B.Sc., F.I.C., and W. G. WEEKS, A.R.S.M., A.R.C.S., F.G.S. .. 232A

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Medal for Student Members. A medal and a prize of five guineas will be awarded annually by the Council to that Student Member of the Institution who shall, in their opinion, have presented a paper of outstanding merit during the session.

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From F. A. Hessel :—

Thèses présentées à la Faculté des Sciences de l'Université de Strasbourg. No. 18. 1924.

From Dr. V. Henny ;—

Problems in the Refining of Cracked Distillates. By Jacque C. Morrell.

From National Supply Corporation :—

The Ideal. July, 1924.

From Koninklijk Instituut van Ingenieurs :—

Register van de Werken van Het Koninklijk Instituut van Ingenieurs. 1920.

From the Imperial Mineral Resources Bureau :—

The Mineral Industry of the British Empire and Foreign Countries. Statistical Summary. (Production, Imports and Exports.) 1920–1922.

From the Mellon Institute of Industrial Research of University of Pittsburgh :—

List of books for 1923, and two copies of booklet entitled "Industrial Fellowships." 1924.

Catalogues :—

Siebe Gorman & Co., Ltd. Reed Roller Bit Company, U.S.A.

For Review :—

From Messrs. C. J. Tagliabue Manufacturing Company, U.S.A. :—

Tag Manual for Inspectors of Petroleum. Edited by R. M. Wilhelm. 18th Revised Edition. 1924.

From the Geological Survey of India :—

The Bauxite and Aluminous Laterite Occurrences of India. By C. S. Fox. Vol. XLIX. Part I.

Records of the Geological Survey of India. Vol. LVI. Part I. 1924. Vol. LV. Part II. 1923.

CANADA.

From High Commissioner for Canada :—

Bituminous Sands of Northern Alberta. By S. C. Ells.

From Mines Branch, Department of Mines, Ottawa :—

The Mineral Industries of Canada. 1924. British Empire Exhibition Edition. 1924.

Department of Mines, Geological Survey :—

Memoir 136. Arnprior-Quyon and Maniwaki Areas, Ontario and Quebec. By M. E. Wilson. 1924.

Memoir 137. Palæontology of the Silurian Rocks of Arisaig, Nova Scotia. By F. H. McLearn. 1924.

Bulletin 38. Contributions to Vertebrate Palæontology. By Charles W. Gilmore. 1924.

AMERICA.

U.S. Bureau of Mines, Department of the Interior :—

Serial No. 2612. Effects of Extraneous Gas on the Production of Oil Wells. In the Lyons-Quinn Field of Oklahoma. By M. J. Kirwan.

Serial No. 2603. Assay Retort Studies of ten typical Oil Shales. By W. L. Finley and others.

Serial No. 2608. Properties of California Crude Oils. And Additional Analyses. By A. J. Kraemer and H. M. Smith. 1924.

U.S. Department of the Interior. Geological Survey :—

Carbon Black produced from Natural Gas in 1922. By G. B. Richardson. II. 29.

Natural-Gas Gasoline in 1922. By G. B. Richardson. II. 30.

Natural Gas in 1922. By G. B. Richardson. II. 31.

Sulphur and Pyrites in 1923. By H. M. Meyer. II. 1.

Professional Paper 132-D. The Evolution and Disintegration of Matter. By F. W. Clarke.

Professional Paper 132-E. An Early Eocene Florule from Central Texas. By Edward W. Berry.

Bulletin 690-B. Gravel Deposits of the Caddo Gap and De Queen Quadrangles, Arkansas. By Hugh D. Miser and A. H. Purdue.

Bulletin 752. Coal Resources of the Raton Coal Field, Colfax County, New Mexico. By Willis T. Lee.

Bulletin 754. The Ruby-Kuskokwim Region, Alaska. By J. B. Mertie junr., and G. L. Harrington.

Bulletin 723. Geology and Ore Deposits of the Manhattan District, Nevada. By Henry G. Ferguson.

Bulletin 746. Geologic Literature on North America, 1785–1918. By John M. Nickles. Part I. Bibliography.

Professional Paper 126. Geology of the Coastal Plain of Texas West of Brazos River. By Alexander Deussen.

Petroleum in 1922. II. 32. By G. B. Richardson.

PERSONAL NOTES OF MEMBERS AND SPECIAL NOTICES.

It is suggested that members send information regarding their movements to the Secretary, for insertion under this heading.

It is with great pleasure that we make the announcement that PROFESSOR J. S. S. BRAME, a Past-president of the Institution, has been appointed Honorary Adviser on Petroleum Matters to the Home Office and to the Board of Trade, posts formerly held by the late Sir Boverton Redwood, Bart.

The many friends of MR. W. A. GUTHRIE will be pleased to learn that he has recovered from a radical mastoid operation to his left ear, and has returned to Egypt.

MR. ALFRED W. NASH, B.Sc., M.I.Mech.E., has been appointed Professor of Oil Mining at the Birmingham University. Professor Nash was appointed Senior Lecturer in this department two years ago.

MR. H. R. BERRY has returned from Burma and is now in England.

LIEUT. J. H. BLAKISTON, R.N.R., has left for Venezuela.

MR. T. E. LANDELL-MILLS is in India, but will be returning shortly.

MR. T. G. MADGWICK has left for a short visit to Egypt.

MR. J. M. MUIR has returned to Mexico.

MR. F. G. RAPPOPORT is now in Persia.

MR. G. E. STOTT is in India.

MR. A. HEDLEY WILLIAMS has been appointed General Manager of the Esthonian Oil Development Syndicate in Esthonia.

The Secretary will be glad to receive information as to the whereabouts of the following members: H. L. J. BUTLER, J. A. CHOWN, W. E. G. HUDSON-HOBDEN, ALBERT JEFFREYS, G. F. MCKILLOP, A. H. NOBLE, and CARL PHILLIPS.

EMPIRE MOTOR FUELS COMMITTEE.

The Report of the Empire Motor Fuels Committee is now available for distribution to members of the Institution, at a charge of 1s., post free. Those desirous of receiving a copy of the report, which contains a mass of useful information, should forward the Secretary a remittance for this sum.

SIR JOHN CASS TECHNICAL INSTITUTE.

The Report of the Department of Petroleum Technology for the Session 1923–1924 has recently come to hand, and the following particulars have been extracted from it:—

In addition to the Session 1923–1924, the Report deals with the three years, 1921–1924, during which the Department has been in operation, thus completing the period for which the contributing oil companies' donations were granted. During the three years 343 students have attended the courses, making a total of 979 class entries and 19,029 hours of attendance.

During 1923–1924 the students numbered 105, with 256 class entries and an attendance of 5,517 hours.

Special lectures on Oil Well and Refinery Technology, and Geology of Petroleum, were given during the Session by Mr. H. Barringer, Sir F. W. Black, Professor J. S. S. Brame, Mr. Ashley

Carter, Mr. A. E. Chambers, Dr. A. E. Dunstan, Mr. J. H. Hope, Mr. J. L. Jeffery, Mr. James Kewley, Dr. W. R. Ormandy, Dr. G. Rudorf, and Mr. J. McConnell Sanders, and were much appreciated.

The Members of the Consultative Committee have again rendered valuable service with advice as to the arrangement of the courses. Owing to pressure of work, Sir John Cadman resigned from the Committee during the session, and Dr. A. E. Dunstan was appointed as his successor.

In arranging the courses for the forthcoming Session, full advantage of the experience gained during the past three years will be taken, especially in differentiating in the courses for those engaged in the clerical, as apart from the technical, branches of the Petroleum Industry.

We have also received the Syllabus of Classes for the Session 1924-1925, which commences on October 6th, 1924.

The courses for this Session comprise (1) a series of technical lectures for those engaged in the clerical, distributive and technical branches of the industry, and (2) a curriculum of study for those engaged in the technical and distributive branches of the industry, including, in addition to the above lectures, courses in the Chemistry of Petroleum, Organic, Inorganic and Physical Chemistry, and Mechanical Drawing. The lectures will be given in two series in successive years, each series consisting of 20 lectures and giving a general survey of the Petroleum Industry.

For those Students having no previous knowledge of experimental science, a preliminary course is arranged giving instruction in Elementary Chemistry, Elementary Physics, and Practical Mathematics.

The courses cover the full Session until June, 1925, the fees for each evening per week being 20s. and for each additional evening 10s.

THE INDUSTRIAL FELLOWSHIPS OF THE MELLON INSTITUTE.

The Eleventh Annual Report of the Mellon Institute Committee of the University of Pittsburgh, by Director E. R. Wiedlein, shows the status of the Industrial Fellowship System.

At the close of the fiscal year, which terminated on February 29, 1924, fifty-two Fellowships were in operation, employing eighty-three research chemists and engineers. During the year $412,132 was contributed by the Fellowship donors, making a total of $2,719,103 for the thirteen years in which the system has been in operation. The Institute itself has expended $494,580 in defraying overhead expenses in the operation of the Fellowships.

Of the Fellowships in operation at the end of the year, thirty-three were individual and nineteen multiple Fellowships. Among them we note No. 385, Oil, the Fellows being W. A. Gruse, Ph.D. (Senior Fellow), R. W. Henry, M.S., and S. P. Marley, B.S.; No. 389, Gas, J. B. Garner, Ph.D.; and No. 417, Oil Well Corrosion, S. H. Gill, Ch.E.

A booklet entitled "Industrial Fellowships," describing the history and research system of the Institute, is now available for distribution to all interested persons.

INTERNATIONAL PETROLEUM EXPOSITION AND CONGRESS.

The International Petroleum Exposition and Congress will be held in Tulsa, Oklahoma, U.S.A., from October 2nd to 11th, 1924. The Exposition will cover an area of seven and one-half acres, and one of the features of the outdoor section will be a replica of Colonel Drake's historic well, including some of the tools and plant used on the original well. Standard, rotary and diamond drilling methods will be demonstrated by complete outfits, and a large array of machinery of all descriptions will be seen in operation.

In connection with the Exposition a Petroleum Congress is being held on October 6th, 7th and 8th, and numerous conventions of oil associations and organisations are being arranged for the Exposition period.

OBITUARY NOTICES.

Sir GEORGE BEILBY, LL.D., F.R.S.

We deeply regret to announce the death at Hampstead, on August 1, 1924, of Sir George Beilby, a Vice-president and Founder Member of this Institution.

Sir George Beilby, who was the son of Dr. G. T. Beilby of Edinburgh, was born on November 17, 1850, and was educated privately and at Edinburgh University. At the age of nineteen he joined the Oakbank Oil Company, and was concerned in various improvements in the process of distilling Scottish oil-shale, among others being a method of treating the spent material with steam to recover the nitrogen as ammonia.

His name is best known, however, in connection with the service he has rendered to the country in his researches in fuel economy. The table which he presented to the Royal Commission on Coal Supplies in 1903, apportioning the British coal output

between its various uses and estimating the saving in each by the use of improved methods, has been repeatedly quoted. From the distillation of oil-shale his attention was attracted to the low-temperature carbonisation of coal, and in 1906 he carried out a series of experiments on the subject and on the briquetting of the coke obtained from it, at the Maryhill works of the Cassel Cyanide Company at Glasgow. At first the subject was dealt with from the aspect of producing smokeless fuel for domestic and other purposes, but the conclusion of Lord Fisher's Royal Commission on Fuel and Engines for the Navy, 1912–1913, that the only way of obtaining fuel oil from home sources was by the development of an industry for carbonising bituminous coal at temperatures far below those used in gas-works and coke-ovens, led to low-temperature carbonisation being regarded from a new point of view.

The problem of maintaining sufficient supplies of fuel oil for the Navy during the war led to the decision of the Department of Scientific and Industrial Research to establish the Fuel Research Board in 1917. Sir George Beilby was appointed Chairman of this Board and also Director of Fuel Research. He at once proceeded to design, construct, and put into operation the Fuel Research Station at East Greenwich, which had two main lines of inquiry—the systematic survey and classification of the various coals of the country, and the treatment of coal by carbonisation and gasification. This second inquiry became largely a study of low-temperature carbonisation, and when he retired from his honorary position in 1923 he had done much towards putting the technical problem on a sound, scientific basis. He remained as Honorary Adviser to the Board and a member of the Advisory Council of the Department. As Director of Fuel Research he was also responsible for the institution of the therm system of charging for town gas.

He has carried out microscopical studies on the cell structure and properties of coke, and also in the experimental investigation of the microstructure and physical properties of solids in various states of aggregation. He dealt with the different aspects of this subject in a number of papers, and in 1921 summarised his results in his book, "Aggregation and Flow of Solids."

He received a knighthood in 1916 in recognition of his services to chemical science, and his work also won him the Fellowship of the Royal Society. He held Honorary Degrees from the Universities of Glasgow, Birmingham and Durham, and served as President of the Society of Chemical Industry, the Chemical Section of the British Association at its meeting in South Africa in 1905, the Institute of Chemistry, and the Institute of Metals, and was a member of the Central Committee of the Admiralty Board of Invention and Research.

Throughout his connection with the Institution of Petroleum Technologists he took the liveliest interest in its progress and success. His loss to chemical science is irreparable, and he will be greatly missed by his many friends and associates.

We are indebted to the *Times* for much of the subject-matter of this obituary notice.

G. E. BROWN.

We regret to announce the death of Mr. G. E. Brown, a Member of this Institution, which took place on July 14, 1924, at Sierra Madre, Los Angeles, California. He was a First Class and Medallist in Mining at the Royal School of Mines, 1902–1904, and in 1906 he also took an Honorary Diploma in Mining there. Until 1913 he was engaged as a surveyor and on mining work in Bolivia and Colombia, and from then until 1920 was Chief Mining Engineer to Messrs. the Langkat Oil Company in the East Indies and the Far East. Mr. Brown was a Member of the Institute of Mining and Metallurgy, an Associate of the Royal School of Mines, and a Fellow of the Geological Society and of the Royal Geographical Society.

C. PERCY HALE.

It is with regret that we learn of the death of Mr. C. Percy Hale, a Member of the Institution of Petroleum Technologists and an Associate Member of the Institution of Electrical Engineers, who died at Lobitos, Peru, on June 14th, 1924.

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REPORTS ON THE PROGRESS OF NAPHTHOLOGY DURING 1923.

Heavy Distillates, Heavy Crudes and Residues.

By Harold Moore, M.Sc.(Tech.), A.I.C., F.C.S.

There is always some difficulty in preparing a review of the advances made in any particular science in a given year. In fact, it is preferable in many cases to take a longer or shorter period instead of exactly a year over which the report is supposed to extend, and on this account a certain amount of latitude should be given to the reviewer. The subject of heavy grades and residues is largely covered by the subject of liquid fuels, and it is certainly from the fuel point of view that the largest quantity of scientific data has recently been published. Of first importance among the papers which have come to hand on the subject of heavy oil burning are the first[1] and second reports of the Diesel Engine Users' Association on Heavy Oil Engine Working Costs. Although not strictly dealing with scientific questions regarding fuel oils, these papers are of exceptional interest, in that they give detailed information of the cost of generating power by means of Diesel engines, and the results of all charges on six stations in this country have been given in great detail. In the earlier report given in 1923, engine costs per unit generated were worked out for a period covering 1917-1921 inclusive. These costs included fuel oil and lubricating oil charges, stores, water, wages and maintenance. The capital charges and charges for operating the electric plant were excluded from the totals. The report issued in 1924 deals with the working cost of 1922 and 1923, and, on combining the two reports, we find that the running costs rose steadily between 1917 and 1920, reaching a maximum of 1·25d. per unit in 1920 for the average of six installations. The year 1921 showed a reduced engine cost, the average figure being 1·03d. per unit, whilst the figures for 1922 showed a further reduction to 0·784d. per unit. The average fuel consumption in the latter report is 0·734 lbs. per unit generated, which corresponds to an over-all thermal efficiency at all loads of 21·1 per cent., this value being based on the assumption that the calorific value of the fuel was 18,500 B.Th.U. per lb. net. This figure of thermal efficiency is of exceptional value, as it is not merely a surmise or a figure given by manufacturers of the engines, but is

[1] *See Journ. Inst. Petr. Techn.*, **9**, 149A. June, 1923.

the actual figure obtained in power stations, taking into consideration the average load factor. It must be borne in mind that Diesel engines in power stations do not run at the most economic loads, but frequently have comparatively low load factors, as it is well-known that they give an efficiency at low loads, which is very little poorer than that obtained at optimum load. As the report points out, "the figure of 21·5 per cent. efficiency could not have been nearly approached by any other commercial form of heat engine under similar working conditions."

On Indian undertakings, the cost for fuel and wages is less than in England; and, coal being difficult to obtain, heavy oil engines will have a very promising future in that country.

A paper dealing with the more scientific side of the question of utilization of heavy fuel oils for internal combustion was read by H. Moore[2] at the end of 1922 before the North-East Coast Institute of Engineers and Shipbuilders. In this paper the difficulties encountered in burning heavy oil are divided into three classes: 1st, ignition difficulties; 2nd, difficulty in burning the oil after ignition has taken place; and 3rd, difficulties caused by the presence of comparatively small quantities of impurities. It is pointed out that the ignition difficulties are only encountered with oils of high spontaneous ignition point, which are almost invariably of aromatic base, and the most serious difficulties of this type are encountered when burning coal tar products. Although occasionally petroleum products contain such a high amount of aromatic constituents as to present these difficulties, the difficulty in actual combustion of the oil after ignition has taken place is dependent upon a large variety of factors, which are each referred to in detail in the original paper. The more important factors are compression pressure, size of engine, presence or absence of blast air, presence or absence of hot bulb, temperature of the circulating water, degree of atomisation, speed of engine and shape of combustion space. It is pointed out that, apart from a very small quantity of ash present in petroleum oil, the oil can be completely burned providing the conditions are favourable, but that with highly asphaltic oils it is frequently difficult to ensure complete combustion during the period available in the working stroke. It is also pointed out that though all asphaltic substances are difficult to burn, the hard asphaltum (insoluble in petroleum spirit) presents much more difficulty than the soft asphaltum (insoluble in alcohol-ether), and that it is the hard asphaltum which creates the well-known difficulty in burning heavy Mexican Oils, such as Panuco Crude. Practical methods of overcoming or reducing some of these difficulties are mentioned in the paper.

[2] *See Journ. Inst. Petr. Techn.*, **9**, 150A. June, 1923.

Coal tars, when burned in the raw state, present similar difficulty to that due to bituminous constituents, and also on account of the free carbon present, which, although combustible, burns very slowly and, therefore, has difficulty in completing its combustion before the exhaust valve or port opens at the end of the working stroke. The impurities which cause difficulty in the combustion of heavy oil are mainly water, ash and mechanical impurities, such as leaves, shavings, bung wrappers, etc. Careful settling, and in some cases centrifugal treatment, will remove these constituents almost completely. Probably the most promising line of development of the use of residual oils at the present time is the high speed oil engine. This was the subject of a most important paper by J. L. Chaloner[3], in which the general engineering principles involved in this engine and a description of the Tartrais and Caruffa engines, etc., was given. The new type of high speed oil engine bears some resemblance both to the cold-starting heavy oil engine and at the same time to the petrol engine. Its construction is in some respects similar to that of the petrol engine, in view of the high speed employed (about 1200 revs. per min.), whilst the cycle of operation is similar to that employed in the cold starting engine, although generally the combustion space is so designed as to facilitate very rapid combustion, which is necessary with an engine operating on heavy oil at high speed. The two-stroke cycle is adopted in the Tartrais engine, probably on account of the greater ease in maintaining a high cylinder-head temperature, and also to allow a larger cylinder by using a small number of cylinders, and still obtaining the same number of impulses as a four-stroke engine employing double the number of cylinders.

The new Beardmore engine which is described in the paper read before the International Air Congress, London, 1923, by A. E. L. Chorlton[4], on the Crude Oil Aero Engine, is a very light high-speed heavy oil engine designed for air-craft use. This engine, which developed 600 brake horse-power, is capable of using light Mexican fuel oil, and weighs approximately 3 lbs. per brake horse power.

In the field of the use of liquid fuels for external combustion the major portion of the work done is connected with the properties of the oils and the use of mixtures of liquid and solid fuels. There are no developments of great importance in the actual burning of oil for steam-raising purposes, and, in fact, it is difficult to see how any great improvements can be made when installations are at present known to give efficiencies in the region of 90 per cent. The main

[3] "High Speed Oil Engines." Paper before Inst. Auto. Engineers. Feb. 15th, 1923.

[4] *See Journ. Inst. Petr. Techn.*, **9**, 216A. August, 1923.

lines on which development is taking place are the designing of installations capable of using liquid fuel in very small units, such as for domestic heating and the like. This is capable of becoming a very large field for the consumption of heavy oil.

R. S. Danforth[5] gives the temperature-viscosity curves of various American fuel oils, and curves connecting the diameters and mean temperatures of pipe lines, together with the temperature drop and pressure loss for oils of different viscosities.

J. P. Persch[6] has patented a method of facilitating the passage of heavy oils through long horizontal pipes by means of hot gases.

Very many researches have been made with a view to reducing the viscosity of some of the more viscous oils, so as to make them more convenient for handling in fuel burning installations. In some cases a high freezing point has interfered with the use of heavy oils, and experiments have been made to reduce the freezing point so as to obviate the necessity for heating pipe lines. I.O. Luchinsky[7] has found that the freezing point of paraffin oil residues can be depressed by the addition of petroleum products containing bituminous compounds. The results obtained in practice were even better than the laboratory results. L. G. Gurwitch[8] suggests improved methods of de-paraffinising Grozny and Surakhany petroleum. A process involving heating of the vapours between the still and the condenser is employed. Sapozhnikoff[9] points out that 70 per cent. of the Grozny output of mazut is of a paraffinoid character, the solidification point being 15° to 25° C. On this account its transportation for use in the railways has been a matter of great difficulty, and an extensive system of pre-heating has had to be installed. He emphasises the importance of finding a practical method of reducing its freezing point and its viscosity at low temperatures. He suggests that the fuel might be used for the preparation of colloidal fuel by the admixture of coal dust.

Similar attempts[10] have been made to resolve the 75 per cent. residue from the distillation of Grozny petroleum, which is solid at ordinary temperatures, into a more mobile liquid for fuel purposes. The adoption of cracking processes, however, was found impracticable on account of the formation of gases and unsaturated compounds. It is suggested that the method might be successful if means were taken to polymerise the unsaturated compounds formed.

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[5] *See Journ. Inst. Petr. Techn.*, **9**, 394. October, 1923.
[6] U.S.P. 1,454,485. *See Journ. Inst. Petr. Techn.*, **9**, 165A. June, 1923.
[7] *See Journ. Inst. Petr. Techn.*, **9**, 102A. April, 1923.
[8] *Ibid.* **9**, 106A. April, 1923.
[9] *Ibid.* **9**, 32A. February, 1923.
[10] *Ibid.* **9**, 440-451. December, 1923.

R. H. Brownlee and W. H. Coburn[11] have conducted investigations using Panuco crude with a view to obtaining a product possessing the characteristics of 14°–16° Baumé fuel oil. It was found possible to do this by the partial cracking of the crude by heat without appreciable coking. A Panuco crude of 12·4° Baumé gravity, on heating to 720° F., gave 36 per cent. of distillates, which after being topped to strip the naphtha, was mixed together with the residue and gave a fuel oil of 160 seconds viscosity Furol at 122° F., the loss being 2·4 per cent. The viscosity of this oil remains practically constant at low temperatures, but it increases rapidly by heating and subsequent cooling, particularly in the presence of moisture and when agitated with air. Fuel oil from Argentine crude oil does not increase in viscosity so rapidly as does that from Panuco crude.

Numerous patents have been taken out in connexion with the use of mixtures of oil and solid fuels, with a view to their employment for steam raising. The main claims of such processes centre on a method of burning coal at a higher efficiency than can be obtained when it is burned in the solid state. There is also good ground for claiming greater convenience in handling, and particularly in storage for marine work, as the volume of the coal dust present in oil solution is considerably less than the volume of the coal in the solid state.

J. A. Leadbeater has taken out a patent for a method of preparing a liquid fuel by grinding up to a colloidal state a mixture of 5 to 10 parts of wet black peat, 30 parts of bituminous coal or other carbonaceous material and one part of tallow or soap. This mixture is reground with 59 to 64 parts of crude oil, or passed through a colloid mill, and is then suitable for use in spray for boiler firing.

R. E. Wilson and H. S. Davis[12] have made experiments on the petroleum oils with a view to comparing their capacities for absorbing benzene. There experiments were made on a fraction collected between 230° and 360° C., that is to say, the heavier end of the kerosene fraction together with gas oil. Cracked distillates and a coal-tar oil were also investigated. It was found that the molecular weight of the higher boiling fractions was about 40 points higher than that of the lower boiling fractions, and for the same range there was little difference between straight-run and cracked distillates. Acid treatment reduced molecular weights 8 to 10 points. The volume of benzene absorbed by the different petroleum distillates, before and after acid treatment, was substantially the same, coal tar oil being a rather better absorbent, but undesirable as regards cost and high viscosity.

[11] E.P. 191,201. *See Journ. Inst Petr. Techn.*, **9**, 97A. April, 1923.
[12] *See Journ. Inst. Petr. Techn.*, **9**, 323A. December, 1923.

J. C. Morell[12] patents a process of making a suspension or emulsion, which may serve as a basis for the preparation of liquid fuel for external combustion. Dispersions of particles of hard pitch and of oily material are obtained in a medium containing 1 per cent. to 5 per cent. of a protective colloid, and the two dispersions then mixed. Suspensions of solid combustible may be obtained by grinding and agitating the substance in such a medium.

Lubricants and Lubrication.

By R. W. L. CLARKE, B.Sc., F.I.C.

A CONSIDERABLE amount of work in this branch has been published during the past year, and it is only possible to deal here with the publications which appear to be of more general interest.

J. C. Morrell and G. Egloff[1] have carried out comparative distillations of a number of American crude oils under atmospheric and reduced pressures. The same percentage cuts were made. The viscosities of the lubricating oil stocks and the percentages of wax are considerably greater in the vacuum distillates. Complete data of the usual characteristics of the fractions are given. With the exception of the products from Mexican crude oil the percentage of unsaturated compounds is lower in the vacuum fractions. H. L. Kaufmann[2] deals with the manufacture of lubricating oil from Mexican crudes and gives a summary of processes and yields. F. N. Williams[3] outlines the methods for obtaining lubricating oils from certain American crudes.

The production of lubricants from lignite tar is the subject of a communication from J. Marcusson and F. Böttger.[4] The light oils from the tar are condensed by heating with zinc chloride or under pressure. The oils have high saponification and iodine values and show a rapid falling off in viscosity with increase of temperature.

The use of high speed centrifugal machines for dewaxing lubricating oil stocks is dealt with by L. D. Jones.[5] The difficulties at first encountered were overcome by the invention of the solid discharge method, using chilled calcium chloride brine as a carrier

[12] U.S.P. 1,440,355/6. *See Journ. Inst. Petr. Techn.*, **9**, 159A. June, 1923.
[1] *J.S.C.I.*, 1923, **42**, 188T. *Cf.* W. L. Gomory, *J.*, 1923, 41A.
[2] *Nat. Pet. News*, **15**, 105.
[3] *Ref. and Nat. Gas. Mfr.*, 1911, **1**, 12.
[4] *Journ. Inst. Petr. Techn.*, 1923, **9**, 94A.
[5] *Ibid.*, 1923, **9**, 334A.

liquid for the wax. The necessary precautions for the success of the process are discussed. Centrifugal separation gave 85 per cent. yield of 15° F. cold test bright stock compared with a yield of 70 per cent. of bright stock of 50° F. cold test by a cold settling process. The use of the high speed centrifuge for dewaxing lubricating oil is further developed by P. T. Sharples.[6] The carrier liquid in the latest type of machine is added separately at the discharge orifice. L. C. Welch[7] also advocates the process for de-waxing Wyoming and Colorado oils.

F. N. Williams[8] shows that the temperature of filtration and mesh of the adsorption agent are important factors in decolorisation of oil by filtration through fuller's earth. E. R. Inman[9] recommends the use of ignited Franklin bog ore as a filtering and decolorising agent and states that it is about twice as effective as fuller's earth.

The chemical composition of mineral lubricating oils is the subject of a number of communications. A. E. Dunstan and F. B. Thole[10] sum up the state of knowledge up to date. They point out that the known facts lead to the conclusion that the unsaturated hydrocarbons in mineral lubricating oil consist to a small degree only of true olefines, while the saturated compounds are principally naphthenic and most probably polynuclear in structure.

J. Marcusson[11] has determined the formolite numbers of certain cylinder oils. Elementary analyses of the formolite compounds are given. Cyclic unsaturated substances, resins and asphaltic bodies yield formolite compounds. The unchanged oils contain olefines, sulphur compounds, alcohols, ketones, paraffins, naphthenes and polynaphthenes. The results indicate that American and Russian oils are composed principally of naphthenes and polynaphthenes. American oils also contain some paraffins and cyclic unsaturated compounds.

C. F. Mabery[12] has elaborated a method for the separation of the lubricant and asphaltic hydrocarbons in petroleum without distillation and has applied the process to four typical oils of American and one of Russian origin. The portion boiling below 300° C. at 30 mms. pressure was first distilled off. The residue was freed from paraffin wax and subjected to repeated fractional solution by heating with mixtures of alcohol and ether. The oils being separated finally into a series of so-called H fractions not dissolved by the hot solvent and a so-called D

[6] E.P. 191,750; *J.*, 1923, **9**, 173A.
[7] *Journ. Inst. Petr. Techn.*, 1923, **9**, 95A.
[8] *Ref. and Nat. Gas. Mfr.*, 1922, **1**, 7-8.
[9] *Oil and Gas. J.*, 1923, **21**, 92.
[10] *Chem. and Met. Eng.*, 1923, **28**, 299.
[11] *Mitt Material prüf*, 1922, **40**, 308; *C.A.* **17**, 748; *Chem. Zeit*, 1923, **47**, 251; *C.A.* **17**, 2185.
[12] *Ind. and Eng. Chem.*, 1923, **15**, 1233; *J.*, 1923, **9**, 427.

series obtained by evaporating the solutions. The Sp. Gr., C. and H content, molecular weight of the final fractions are tabulated. The molecular weights were determined by a cryoscopic method, using stearic acid as the solvent. The agreement between the observed values and those calculated from the assigned formulæ is good. Hydrocarbons of higher molecular weights and C/H ratios accumulate in the insoluble fractions (H series). Members of the series C_nH_{2n}—4, C_nH_{2n}—8, etc., to C_nH_{2n}—20, but no naphthene C_nH_{2n} hydrocarbons have been isolated. Some observations indicate the existence of carboxyl derivations in American petroleum.

G. L. Oliensis[13] deals with the sulpho-acid bodies which may be present in lubricating oils refined by treatment with sulphuric acid and discusses the formation and breaking of emulsions in the subsequent washing process. He points out that the addition of a water soluble soap and agitation with steam will often break persistent emulsions caused by oil soluble emulsifying agents. The Vacuum Oil Co.'s steam test and the more exact Conradson demulsibility test are shown to be of value in detecting the presence of deleterious bodies in lubricating oils.

W. H. Herschel[14] discusses at length the significance of the usual laboratory tests for the quality of lubricating oils in relation to their behaviour in service.

F. N. Williams[15] compares paraffin and asphalt base lubricating oils. Regarding viscosity he considers that there is very little difference between the two oils over the normal working range. In the Conradson test the asphalt base oil gave a lesser amount of carbon than the paraffin base oil. The carbon from the former was soft and flaky and that from the latter hard and gritty.

M. A. Rakusin[16] compares mineral and vegetable lubricating oils. A cylinder oil was found to possess a much flatter viscosity curve after thorough refining than before refining. The viscosity at 80° C. was 16·82 min. at 80° C. and 1·67 min. at 190° C. and after refining 8·46 min. at 80° C. and 1·36 min. at 190° C. Blown rape oil should not be used for compounding.

W. F. Parish[17] discusses the danger of crank case dilution of lubricating oil in internal combustion engines and traces the increased demand in recent years for heavier lubricating oils and increased sale of spare moving parts to the use of heavier fuels with increased final B.Pt. Crank case dilution increases regularly to a point where a balance occurs and excess leakage of fuel is thrown

[13] *Ind. and Eng. Chem.*, 1923, **15**, 690.
[14] *Journ. Inst. Petr. Techn.*, 1923, **9**, 170A.
[15] *Ibid.*, 1923, **9**, 171A.
[16] *Ibid.*, 1923, **9**, 170A.
[17] *Ibid.*, 1923, **9**, 327A.

off through the crank case release. Engines and crank cases should on no account be washed out with anything but clean lubricating oil. The safe limits to which crank case dilution of different grades of oil can be allowed to proceed are specified.

H. Moore[18] discusses the lubrication of heavy oil engines and concludes that high viscosity oils are unnecessary. Oils for enclosed high speed engines must have high flash point to avoid crank case explosions. The lubrication of the air compressor is more difficult than that of the engine. Acetic and formic acids have been found in the liquid from such compressors. The formation of these acids is minimised by the use of oils of low iodine value.

The reclamation of used petroleum lubricating oil is now receiving serious consideration. W. H. Herschel and A. M. Anderson[19] reclaim used turbine oil by heating to 60–70°, addition of a coagulant, agitation and settling or by blowing live steam into it and centrifuging. In a continuous by-pass filtering system for turbine oil, the acidity developed tends to remain in the sludge. Motor oils may be reclaimed by blowing steam through them to drive off fuel residues, adding small quantities of soda agitating and settling. These authors proceed to deal with the influence of acidity on demulsibility and interfacial tension of lubricating oils and conclude that used oils are equally serviceable if they satisfy the same test as new oils. The G.E.C.[20] have developed an electrically heated apparatus for reclaiming motor oils. An unsigned article, "The A.B.C. of lubrication,"[21] deals in outline with the refining of lubricating oils and proceeds to discuss crank case dilution and the reclaiming of used motor oils.

E. H. Leslie and J. C. Geniesse[22] have measured the specific heats of six typical lubricating oils over a range of temperature from 100° F.–290° F. An increase of 35–40 per cent. in specific heats was observed. This increment is too large to be ignored in certain engineering calculations.

M. Okochi and M. Majima[23] have determined the viscosity of various oils at temperatures ranging from 27° C. to −18° C., and M. D. Hersey[24] has investigated the viscosity of lubricants at high pressure and temperature by means of a rolling ball viscometer, modified for use on high pressures up to 4000 kg./cm.^{2} (about 50,000 lb./in.^{2}). Hyde showed that the effects of a pressure of

[18] *Jour. Inst. Petr. Techn.*, 1923, **9**, 335A.
[19] *Ibid.*, 1923, **9**, 94A.
[20] *Ibid.*, 1923, **9**, 96A.
[21] *Pet. Age*, 1923, **11**, 56.
[22] *Journ. Inst. Petr. Techn.*, 1923, **9**, 327A.
[23] *Ibid.*, 1923, **9**, 218A.
[24] *Ibid.*, 1923, **9**, 218A.

1200 kg./cm.^{2} on the viscosity of fixed oils, as a class, were less than on mineral oils. At the higher pressures and temperatures now employed this distinction tends to disappear.

Steady progress is being made in the scientific study of lubrication. T. E. Stanton[25] discusses the nature of lubrication in engineering practice prefacing the experimental part of his paper with an interesting historical review of the scientific work which has been carried out on lubrication. It is pointed out that there are two essentially different kinds of lubrication. In the one known as the Reynolds type the surfaces are separated by a film of lubricant many hundreds of molecules in thickness. In the other termed by W. B. Hardy, " boundary " lubrication, the lubrication is a function of the nature of the surfaces and the chemical constitution of the lubricant. Attempts to obtain the condition of boundary lubrication in a heavily loaded continuously rotating journal and bearing were unsuccessful. The apparatus then devised consisted essentially of a grooved journal which is made to oscillate by means of a heavy pendulum in a bearing having similar spiral grooves cut in the opposite direction at right angles to those on the journal. The total arc of contact of the journal and bearing is restricted to 45° on either side of the vertical by cutting away the metal of the bearing outside this arc. By means of a simple locking screw device the pendulum can oscillate independent of the journal on ball bearings or with the journal as desired. The lubricant is supplied by a sight feed lubricator and oil bath conditions are obtained. The coefficient of friction is calculated from the observed damping of the oscillations of the pendulum. The results show that the characteristics of lubricants and bearing metals under the conditions of boundary lubrication can be rapidly investigated. Also that the lubrication of all machine details in which the relative motion is of a reciprocating character may be taken as boundary lubrication. The quantitative results for castor oil, Bayonne, Shell Mex Super Heavy and Bayonne oil plus 1 per cent. of oleic acid are given. The contention of H. M. Wells and J. E. Southcombe that 1 per cent. of free fatty acid added to mineral oils produces a marked reduction (17 per cent.) in the coefficient of friction is confirmed.

W. H. Herschel[26] deals with the friction testing of lubricating oil and proposes a new method for plotting the results of tests on oil friction testing machines. The co-efficient of friction is calculated as usual and plotted against Sommerfeld's criterion S where $S=\frac{\mu n}{p}\left(\frac{d}{2\Delta}\right)^2$ where μ=viscosity in poises, n=revs. per sec.,

[25] *Journ. Inst. Petr. Techn.*, 1923, **9**, 260.
[26] *Ibid.*, 1923, **9**, 93A, 171A.

p=press. in dynes per cm.^{2}, $\frac{d}{2\Delta}$ ratio of diam. of journal to difference between diam. of journal and bearing. A Cornell testing machine was used in which the journal was given a to and fro reciprocating as well as rotational motion, the most interesting results being obtained near the point of seizure. Numerous graphs show the results of the test. The results of other workers are discussed and the conclusions arrived at are: (1) That there is no experimental evidence that the value of Sommerfeld's criterion at the point of minimum friction decreases as oiliness improves. (2) That journal friction testing machines are not convenient for measuring oiliness owing to changes of clearance with wear.

A. E. Dunstan and F. B. Thole[27] discuss the property of oiliness and are of the opinion that the unsaturated molecules of the lubricant enter into firm physicochemical union with the metallic surfaces forming a friction surface, which is a compound of oil and metal. This is in accord with the views of W. B. Hardy and of Wilson and Barnard. It would appear that the opinion that boundary lubrication is an adsorption phenomenon is becoming well established.

C. M. Johansen[28] and H. Dimmig[29] have investigated the values of interfacial tension of lubricating oils and discuss the application of interfacial tension values in relation to lubrication practice.

W. B. Hardy and I. Doubleday[30] publish further work on the lubricating properties of individual chemical substances under "boundary" conditions. It is pointed out that when a lubricant is first applied friction does not reach a steady value immediately. This latent period seems to correspond to the time required for orientation of the molecules in the primary film. The latent period is shortened by rise of temperature or dilution with a n-paraffin. When a n-paraffin is added to an alcohol or acid the friction remains that of the alcohol or acid until the paraffin makes up 99 per cent. of the mixture.

The British Electrical and Allied Industries Research Association issue a report on the properties and testing of insulating oils. Trouble from oil in transformers is generally due to the presence of air, which oxidises and polymerises the oil, causing deposits to settle in the windings and overheating. The Michie sludge test and the B.T.H. evaporation test are regarded as satisfactory.

G. Brühlmann[31] discusses the importance of using low cold test

[27] *Chem. and Met. Eng.*, 1923, **28**, 300.
[28] *Ind. and Eng. Chem.* **16**, 132; *J.*, 1923, **9**, 99A.
[29] *Proc. Amer. Soc. Testing Materials* **23**, I., 363.
[30] *Proc. Roy. Soc.*, 1923, **25**, 104A; *J.*, 1923, **9**, 220A.
[31] *Journ. Inst. Petr. Techn.*, 1923, **9**, 95A.

oils for transformers and switches and describes a new method for determining solidifying point.

F. Schwarz and J. Marcusson[22] suggest that the "tar number" of transformer and turbine oil should be determined as a test for purity. The "tar number" is taken to be the amount of matter extractable by alcoholic caustic soda solution after the oils have been heated to 150° C. for 50 hours.

Special Products.

By F. G. P. Remfry, B.A., D.Sc., A.I.C.

Carbon Black.

Jakowsky,[1] working on the production of carbon black from natural gas by means of the high voltage arc found that a magnetically-spread arc was not successful, but that the intermittent and continuous types of apparatus showed promise. With the former type the maximum yield of carbon per k.w.-hour input is obtained with 6 amps. flowing in the primary circuit, and an input of 41 k.w.-hour/lb. of carbon recovered. In the continuous system the yield per k.w.-hour is less when water is used as wash solution than with oil, large quantities of CO and CO_2 indicating a reaction between hydrocarbons and dissociated water vapour. Green[2] successfully distinguished gas carbon black from lampblack under the microscope when examining paint and rubber pigments. The former has particles of 0·15μ diameter, and appear greyish or brownish whilst the latter are black and 0·3—0·4μ diameter.

Davies[3] suggests that, in view of its adsorptive capacity, carbon black should be used as a medium for introducing curatives, gases, etc. into rubber.

Marchwald and Frank[4] made comparisons between German lampblack and American gas-black, and showed that vulcanised rubber containing the latter had a higher tensile strength and elongation, but less resilience than rubber containing any grade of lampblack. Microscopic examination, however, gave no satisfactory explanation of the difference in properties.

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[22] *Journ. Inst. Petr. Techn.*, 1923, **9**, 95A.
[1] *Bur. Mines Repts. Investigations* No. 2417, 1922.
[2] *Chem. Met. Eng.*, 1923, **28**, 53.
[3] *India Rubber Review*, 1922, **22**, 16.
[4] *Gummi-Ztg.*, 1921, **36**, 1459; 1922, **37**, 5.

In an account of the manufacture and use of carbon black in France, Oswald[5] describes how, in the absence of natural gas, the French obtain a yield of 50–55 per cent. by burning the ever-increasing supply of naphthalene and anthracine, as compared with a yield of 1·5–3·5 per cent. from CH_4.

Activated Charcoal.

An instructive paper by Ray[6] deals with the structure of activated charcoal. Gas-adsorbing charcoal requires the maximum adsorptive capacity per unit of volume whilst decolorising charcoal should be highly porous and traversed by relatively large pores capable of adsorbing colloidal particles and large molecules. The fundamentals of the Chaney oxidation process are described, and it is shown that, by activating suitable raw material by a modification of the Chaney process, carbons can be prepared that possess the desired characteristics for any application.

In order to obtain a gas of high calorific value from distillation gas Fischer[7] passes the latter over activated charcoal which adsorbs the required materials. These are recovered by simple heating of the charcoal, which was cheaply manufactured by carbonising lignite at 800° in steam. This charcoal was capable of adsorbing 22 per cent. of its weight of benzene from air as compared with 25 per cent. by cellulose charcoal.

In another paper Ray[8] gives an account of the properties necessary in activated charcoal for commercial use, a description of the numerous uses to which it can be put, and adds an excellent bibliography on the subject.

The cause of the activity of certain varieties of charcoal was investigated by Ruff[9], who concluded that it was due to the atoms or atom groups of foreign materials bound to the surface of the charcoal. These atoms are the cause of the specific properties of active charcoal, and are characterised by the firmness of their linking to the carbon atoms on the surface. Other atoms can also attach themselves to the surface, but they are easily replaced, and are not firmly bound.

Paraffin Wax.

The composition of paraffin wax has been investigated by Francis[10] by means of oxidation by air or oxygen. A number of oxidation

[5] *Caoutchouc and gutta-percha*, 1922, **19**, 11,641.
[6] *Chem. Met. Eng.*, 1923, **28**, 977.
[7] *Brennstoff-Chem.*, 1922, **3**, 370.
[8] *Chem. Met. Eng.*, 1923, **29**, 354.
[9] *Kolloid Z.*, 1923, **32**, 225.
[10] *J. Chem. Soc.*, 1922, **121**, 496, 1529, 2804.

products were obtained and their properties classified, but identification was not carried very far.

Grun and Ulbrich[11] showed that the yield of acids from paraffin wax by oxidation with air at 160° C. increases with the quantity of air passed in a given time. Traces of moisture in the air are beneficial whilst the presence of CO_2 retards oxidation.

Siebneck[12] treated brown-coal paraffin wax with oxygen at 13° C. for 55 hours, and found that there were distinct stages, esterification being the primary reaction, and the formation of acids being a secondary reaction by decomposition of the esters.

Waterman and Perquin[13] studied the action of heat and pressure on paraffin wax with and without the presence of hydrogen. The products obtained with hydrogen were slightly less unsaturated than the others, but the difference between the two products was not sufficient to prove that much, if any, hydrogenation had taken place.

Pyhala[14] found that a convenient method for determining the specific gravity of paraffin wax was to float it in alcohol-water mixtures and determine the specific gravity of the latter.

In working on the theory of adsorption Gurvich[15] found that the adsorption of paraffin wax from organic solvents by charcoal was rather high, which is directly contrary to the ideas of Freundlich on adsorption phenomena.

Porter and Hedges[16] examined emulsions of paraffin in water and found that there was an increase in concentration of the particles with height, reckoning from the bottom, which results agreed with those calculated from a previously developed equation.[17]

Vaseline.

Pyhala[18] has found that in measuring the dropping point of vaseline with the Ubeholde apparatus variations in results could be avoided by first melting the vaseline on a glass plate and allowing it to congeal thereon, which has the effect of making it more homogeneous.

The extraction of vaseline from paraffinoid-petroleum residue (mazout) is described by Hazanovitch[19]. The mazout is dissolved in light benzine, treated with a mixture of petroleum soot and bone

[11] *Z. angew Chem.*, 1923, **26**, 125.
[12] *Petroleum Z.*, 1922, **18**, 1193.
[13] *Proc. Acad. Sci. Amsterdam*, 1923, **26**, 226.
[14] *Petroleum Z.*, 1922, **18**, 1164.
[15] *Kolloid Z.*, 1923, **32**, 80.
[16] *Trans. Faraday Soc.*, 1923.
[17] *C.A.*, **16**, 4104.
[18] *Petroleum Z.*, 1922, **18**, 1164.
[19] Russian Petroleum Congress, 1922. *Journ. Inst. Petr. Techn.*, **9**, 103A, April, 1923.

charcoal, filtered through bone charcoal and the benzine distilled off with steam. The yellow medicinal material thus obtained can be decolorised completely by treatment with fuming sulphuric acid and alkali.

Oxidation Products of Petroleum.

The formation of aromatic hydrocarbons from aliphatic compounds was brought about by Piotrowsk and Jakubowicz[20] by passing certain fractions of Boryslaw crude petroleum over MnO_2 as a catalyst in an iron tube heated to 550–600° C. The fraction boiling 60–180° was almost entirely converted to unsaturated compounds, but, by altering the catalyst, large yields of aromatic hydrocarbons may be obtained.

The ozonides of petroleum are of interest for the possible formation of resins, for refining by means of their formation and removal, and as analytical data depending on the extent of formation in an oil. Koetschan[21] obtained 25% yields of ozonides which had an average molecular weight of 663 when determined immediately. After several hours, however, the figure fell to 606, and to 479 after two days. As prepared, the ozonides were white solids which became red in colour unless kept at a low temperature. If the oils are first purified with $Al Cl_3$ and the sulphur content thereby reduced the ozonides are quite stable.

Elworthy[22] effected the partial oxidation of methane in natural gas to formaldehyde by passing the gas, with oxygen, over catalysts such as magnetite, oxides of Fe, Cu, Ag, Co, borosilicate glass and Pt. Traces of formaldehyde only were thus obtained, but by means of the silent electric discharge a viscous liquid containing polymerised aldehydes and resins was formed which gave promise of practical utility. Wheeler and Blair[23] have carefully investigated the conditions necessary for obtaining the maximum yield of formaldehyde by oxidation of methane. They found that the thermal decomposition of methane is slower than its oxidation rate, but below 850° C. no complications arise from this source during periods of heating of one second, whilst a temperature of at least 600° C. is necessary to obtain a reasonable amount of reaction in a short period. To isolate formaldehyde, the time of reaction must be short, since decomposition commences at 310° C. and slow oxidation and a short heating period are the main factors in obtaining a good yield of formaldehyde. Some experiments

[20] *Petroleum Z.*, 1923, **19**, 5.
[21] *Z. angew. Chem.*, 1922, **35**, 509.
[22] *Trans. Roy. Soc. Canada*, 1922, **16**, 93.
[23] *J. Soc. Chem. Ind.*, 1923, **42**, 81T.

have been carried out by James and Zeisenheim[24] on the use of oxidised kerosene and gas oil in internal-combustion engines with the idea that better combustion would thereby be obtained. This seems to have been borne out by the fact that the power output was equal to that from unoxidised fuel though the thermal value was one-eighth less. The oxidised fuels also showed less tendency to detonate and therefore act, in a way, as anti-knock compounds.

Chlorine Compounds of Petroleum.

The chlorination of methane has received a fair amount of attention judging from the number of patents dealing with this subject which mostly depend on some catalyst or actinic light to bring about combination. Schleede and Luckow[25] passed chlorine and methane through electrically heated quartz tubes and found that when molar proportions are employed the mixture burns but dies out unless excess of chlorine is present. The addition of chlorine is only quantitative if the temperature is kept above a certain point depending on the composition and rate of flow of the mixture. Catalysts do not assist the reaction. When the velocity of the gases per unit area exceeds a certain value, higher products are formed at the expense of chloroform. The production of carbon tetrachloride is only observed if the heating surface is enormously increased, as by the use of activated charcoal, when the rate of flow is below the ignition value, and when considerably below that point carbon tetrachloride and bodies of similar boiling point are formed at the expense of methyl and methylene chlorides.

Chemistry.

By F. B. Thole, D.Sc., F.I.C., F.C.S.

It is very difficult to form an opinion from the amount of published work on the pure chemical side of petroleum research as to the actual progress of knowledge on this subject. Admittedly the extraordinary complexity of the raw materials available and the lack of knowledge as to the identity of the individual components renders work on this subject exceedingly difficult, while, as a rule, commercial considerations divert in other directions the activities of the chemists who specialise in petroleum research.

[24] *Chem. Met. Eng.*, 1923, **28**, 543.
[25] *Ber.*, 1922, **55**, 3710.

Nevertheless, there is considerable evidence that the amount of research carried out is far in excess of that published, so that the paucity of new knowledge summarised in this section cannot fortunately be taken as evidence of lack of progress in this branch of chemistry, and it is to be hoped that in the years to come information on the chemical aspect of petroleum will become more accessible to those interested than it has been in the past.

The problem of the probable origin or origins of petroleum has continued to attract attention, but discussion, though interesting and sometimes illuminating, is rarely supported by definite evidence.

The principal researches on this subject are due to Pyhala[1], who points out with considerable dexterity the weak points in the now generally accepted view that petroleum is a product of accumulations of marine growth—both vegetable and the associated animal matter. Pyhala has shown that it is not difficult to polymerise and condense the more mobile unsaturated hydrocarbons such as may be obtained by the action of water on carbides to oils of high molecular weight. He also brings forward the more weighty argument that although the known optical activity of certain Baku petroleums has been taken as proof of its organic origin, no traces of cholesterol or its derivatives have been identified; on the other hand, optically active hydrocarbons have been isolated. Pyhala considers it probable that the optically active substances (hydrocarbon or otherwise) found in petroleum are accessory products of vegetable origin which have been taken up by the oil in the course of migration.

The widespread occurrence of traces of nickel in the ash of oils has received frequent comment from various writers, and Ramsay[2] gives analyses showing the nickel content of many oils. He points out that as a rule the oils richest in nickel are those richest in hydrogen—*i.e.*, the paraffin type. There are, of course, numerous weighty objections to this catalytic theory of petroleum formation, among them the fact that elemental nickel is never discovered in association with petroleum; but the almost invariable presence of nickel in petroleum is undoubtedly a fact of more than ordinary interest.

The isolation from crude petroleum and from its products of distillation of definite chemical entities is of fundamental importance in the chemical investigation of petroleum, and in spite of the very great difficulties several valuable researches have to be recorded. It is now accepted that the hydrocarbons and other components of petroleum are far less stable to heat than was formerly supposed, and that at temperatures even below 200° C. thermal decomposition

[1] *Petroleum*, 1923, 535.
[2] *J. Soc. Chem. Ind.*, 1923, 287T.

occurs, so that the distillates cannot be taken as representative portions of the original oil. Consequently, other physical methods which do not involve risk of chemical transformation of the hydrocarbons must be sought. Gordon[3] has shown that if Hardstoft oil is fractionated by regulated precipitation of its ether solution with 90 per cent. alcohol the fractions have low and approximately equal iodine values, whereas distillate fractions have regularly increasing iodine values. Another popular view, that because crude oil on cooling deposits a colloidal waxy material whereas after distillation this wax is obtained in a crystalline form, the latter is a decomposition product of the former "proto-paraffin," is discredited by Gordon, who by diluting the crude oil with ether has been able to crystallise out the wax. He considers that in the crude oil the wax is maintained in an uncrystallisable condition by certain protective colloids.

A certain separation indicated by differences in specific gravity was achieved by fractional emulsification with soap solution. The study of the components of the lighter fractions is a simpler problem and has already been fairly thoroughly worked out in past years. One of the most effective methods appears to be Herzfelder's method of regulated bromination, whereby definite bromo-derivatives are easily obtained and isolated. Reduction by zinc and alcohol reconverts these into the purest hydrocarbon. Mabery[4] has also applied the method of fractional solution to the separation of hydrocarbon mixtures, the process being applied to the residues boiling above 300° C. from various American and Russian petroleums.

Repeated fractionation with alcohol-ether was employed and the various fractions were analysed. It was found that from many heavy oils two well-defined series of hydrocarbons are obtainable, a more soluble amber-coloured series with good lubricating properties and a less soluble black and sticky series. The former gives a crystalline nitration product and the latter an oily acid product.

Pennsylvanian oils are rich in the former series and Baku oils in the latter series.

Stäger[5] has attempted to remove the sludge-forming components of transformer oils by extraction with methyl alcohol. The extract consisted largely of unsaturated cyclic hydrocarbons, but the oil after extraction still sludged badly.

Easterfield and McClelland[6] have described in detail New Plymouth crude, a New Zealand oil which contains 12 per cent. of wax, and which solidifies as it issues from the well. The benzine and kerosene fractions are rich in naphthenic and aromatic hydro-

[3] *J. Soc. Chem. Ind.*, 1923, 405r.
[4] *Ind. and Eng. Chem. Jour.*, 1923, 1233.
[5] *Helv. Chim. Acta*, 1923, 893.
[6] *J. Soc. Chem. Ind.*, 1923, 936.

carbons and methyl-cyclopentane, cyclohexane, methyl- and dimethyl-cyclohexanes, naphthalene and methyl-naphthalene have been isolated.

A series of naphthenic acids have been isolated in a pure state from Japanese petroleum by Tanaka and Nagai.[7] The crude acids were converted into methyl esters, and by careful fractionation and subsequent hydrolysis tri, tetra and pentadecanaphthenic acids were obtained as colourless, odourless liquids with no iodine value. No evidence was obtained as to their chemical structure.

Marcusson[8] has repeated Nastukoff's determinations of the "formolite number" of various American oils, and considers Nastukoff's results to be about 500 per cent. too high. The chemistry of the formolite reaction is so little understood that it is quite probable that each investigator is correct; there is no evidence as yet that for a mineral oil the formolite number is any more definite a criterion than the iodine number, which is also largely dependent on the experimental conditions. Marcusson considers that both American and Russian lubricating oils both consist principally of naphthenes and polynaphthenes, and that the former also contain paraffins and cyclic unsaturated hydrocarbons.

The possibility of using the Grignard Reagent as a means of characterisation of olefinic hydrocarbons has been suggested from time to time, but apparently on an inadequate basis, for Gilman and Crawford[9] have shown conclusively that pure olefines are quite non-reactive towards the reagent.

The polymerising effect on olefines of adsorbent earths, originally noticed by Gurwitsch, has been further studied by Venable[10], who has shown that α-pinene when filtered through fuller's earth is rearranged to dipentene and also polymerised to dipinene and other polyterpenes. Many other terpenes behave similarly.

The behaviour of the olefinic hydrocarbons in lubricating oil on treatment with sulphuric acid, has an important bearing on the refining operations. Oliensis[11] has shown that the diolefines are converted into an insoluble sludge; if this is not completely separated it yields on subsequent neutralisation oil-soluble colloids which give rise to water-in-oil emulsions. Mono-olefines give oil-soluble sulphuric acid esters which remain in the oil. Aromatic hydrocarbons give sulphonic acids which are removed by the alkali wash and oxidation products (naphthenic acids), which on

[7] *J. Soc. Chem. Amer.*, 1923, 754.
[8] *Chem. Zeit.*, 1923, 251.
[9] *J. Soc. Chem. Amer.*, 1923, 554.
[10] *J. Soc. Chem. Amer.*, 1923, 728.
[11] *Ind. Eng. Chem. Jour.*, 1923, 690.

neutralisation give water-soluble soaps which tend to form oil-in-water emulsions.

This work is striking confirmation of the important observations of Brooks and Humphrey on the effect of sulphuric acid on the lower olefines met with in cracked spirit.

A very informative report on certain important characteristics of transformer oil has been issued by the British Electrical and Allied Industries Association, who have carried out a comprehensive research scheme during the past few years. The report proves that overheating in transformers is generally due to oxidation of the oil and consequent sludge formation. The Michie test is much superior to the Kissling test or the iodine value as an indication of the tendency of the oil to sludge; it is recommended that air and not oxygen should be used for the test, although this naturally makes the operation more lengthy and tedious.

The desulphurisation of petroleum products is a problem which confronts the refiners of most mineral oils, and both chemical and physical processes are used to this end. The classical sulphuric acid-soda operation is effective though messy and wasteful, while other long known methods such as the Frasch and the sodium plumbite appear to be very limited in their application and have been largely replaced by more efficient processes. According to Brocke[12], the Frasch process is nearly valueless with Mexican oils, while acid washing was quite effective. Sodium plumbite, as might be expected, was no more effective than caustic soda, while the customary addition of sulphur to precipitate the colloidal lead compounds (sulphide and mercaptides) is positively harmful as the element dissolves in the oil and renders it very corrosive to copper and copper alloys.

The "cracking" of the cheaper fractions of petroleum for the production of gasoline has developed steadily during the year. Of the two alternative processes—vapour phase and liquid phase—the latter appears to have entirely ousted the former, no doubt on account of the much smaller gas yield and the smaller proportion of olefines and diolefines in the resultant spirit. In all the principal modern processes the oil is heated to its cracking temperature under sufficient pressure to maintain it in the liquid phase and allowed to pass into lagged settling chambers in which the carbon is deposited.

Emerson[13] claims to assist cracking to a marked degree by arranging that jets of the oil shall meet at extremely high velocities in a heated chamber.

Plauson[14] uses zinc chloride in place of the aluminium chloride

[12] *Brennstoff-Chem.*, 1923.
[13] E. P. 163,277 and 168,573.
[14] E. P. 193,071.

employed in the McAfee patents as a cracking catalyst and claims to obtain an excellent product.

The Bergius method of hydrogenation under very high pressures has been investigated by various workers, but the results in most cases have not been divulged and opinions as to its effectiveness appear to differ. Waterman and Perquin[15] consider that they have obtained positive evidence of the hydrogenation of the products obtaining by cracking paraffin wax at 435° C., the products having a lower specific gravity and bromine number than parallel products formed in the absence of hydrogen.

Colingaert[16] has studied the thermal decomposition of normal and isopentane at the lowest practicable temperature (600° C.), under which conditions 30 per cent. of the gas suffered decomposition. With normal pentane 55 per cent. of the gas decomposed was converted into ethane and propylene and 25 per cent. into ethylene and propane. With isopropane rupture of the chain occurs on one side or other of the branch.

The gases resulting from the cracking of petroleum are of course a potential source of many valuable products, but so far their utilisation has been complicated by the number of olefines present. Stewart[17] proposes to dissolve the propylene and higher olefines by passage through cold petroleum oil, the less soluble ethylene passing on undissolved.

The synthesis of certain valuable organic chemicals by the direct oxidation of petroleum hydrocarbons has attracted attention for some years past. Wheeler and Blair[18] have examined in detail the best conditions for the oxidation of methane to formaldehyde, and find that a temperature above 600° C. is necessary, but as formaldehyde decomposes at 310° C. the time permitted for the oxidation must be made very short. No complications arise below 850°C. from the thermal decomposition of the methane.

Elsworthy[19] finds that the silent discharge on a mixture of methane and air gives a liquid containing polymerised aldehydes and resins, methyl alcohol and formic acid, products derived from formaldehyde by secondary reaction.

Schonfelder[20] has obtained 55 per cent. yields of formaldehyde by passing methane, steam and air over copper or silver gauze at 500° C. The oxidation of olefines proceeds more readily and good yields of acetaldehyde result from the oxidation of ethylene.

The chief difficulty in the conversion of methane into methyl

[15] *Proc. K. Akad Wetenach*, 1923, 226.
[16] *J. Amer. Chem. Soc.*, 1923, 130.
[17] U. S. P. 145,322.
[18] *J. Soc. Chem. Ind.*, 1923, 81T.
[19] *Trans. Roy. Soc. Can*, 1923, 93.
[20] *Ber. Ges. Kohlentechnik*, 1923, 247.

alcohol through the intermediate stage of methyl chloride lies in the resistance of the latter to hydrolysis. McKee and Burke[21] recommend the use of milk of lime at 330° C., which gives a 67 per cent. yield. If alumina is used the chief product is dimethyl ether.

The most important work on the oxidation of the hydrocarbons in paraffin wax was published in 1922, but further work has been done by Grua and Ulbrich[22], who, by increasing the flow of air ten times, double the yield of acids. The reason for this probably lies in the improved agitation. Moisture was found to accelerate and carbon dioxide to retard the oxidation.

A complex mixture of alcohols and ketones, "synthol," suitable for a motor fuel has been obtained by Fischer and Tropoch by passing water gas over a catalytic mass of iron filings and potassium carbonate at 100–150 atmospheres pressure. The composition of this product has not yet been fully determined, but the detailed analysis will probably prove of considerable interest.

Analysis and Testing of Petroleum.

By S. Bowman, F.I.C.

One result of the ever increasing utilisation of Petroleum and its products, is that more and more attention is being given to methods of analytical procedure. Whereas in the past this was commonly known as "testing" and consisted of comparatively simple operations, mainly of a physical nature, recent chemical research and modern refinery practice has considerably widened the scope of analytical examination and now demands the highest skill and technique obtaining in the older chemical industries.

Perhaps the most important feature of the year in this connexion has been the adoption of standard methods. Representative Committees were set up by the Institution of Petroleum Technologists to investigate the best known methods and lay down detailed procedure and apparatus. The work has been modelled on the lines of, and closely conforms to, the American Society for Testing Materials Standards except in those cases where certain instruments, *e.g.*, Redwood Viscometer and Lovibond Tintometer, have become established by long practice in this country.

[21] *J. Soc. Chem. Ind.*, 1923, 682.
[22] *Z. angew. Chem.*, 1923, 125.

The members of the Standardisation Committees are to be congratulated on the manner in which they have carried out their respective tasks and for the clear and concise wording of the text. "Standard Methods of Testing Petroleum and its Products"* will come up for revision periodically and will become indispensable to all analysts and petroleum technologists.

Kroch[1] criticises the formula given by Engler for correction of Specific Gravity to 15° C. and shows this to give an error of three units in the third decimal place. Kroch suggests $d_{15} = d_t(1+a(t-15))$.

A new apparatus[2] for determining the Specific Gravity of natural gas consists of an orifice and capillary tube in the same gas line with a differential gauge for each. The principle is based on the fact that when a fluid is passed through a thin sharp edged orifice the drop in pressure at the orifice varies with the density of the fluid.

Klaus[3] indicates errors introduced in the specific gravity determinations when using a Mohr's Balance due to capillarity and the difference in volume of the weights and the sinker employed. Specific gravity of vaseline and other semi-solid products is conveniently determined by the flotation method using alcohol-water mixtures.

A new type of surface tension balance[4] has been devised using the drop weight method. Less than five drops of liquid are necessary and the surface tension is indicated on the scale in dynes per cm. Two similar flasks connected to a manometer tube and means whereby glass containers full of the liquid may be broken inside the flask afford a convenient method of determining vapour pressure.[5]

An ingenious method[6] for the valuation of lubricating oils consists of a journal, on the front surface of which is drawn a cross hatched lattice with lines 0·002 mm. apart. On rotation the point of intersection of the axis of the shaft with the plane of the lattice appears as a fine point and any displacement is measured microscopically.

The International Union for Pure and Applied Chemistry, 1922, recommend the use of benzoic acid for standardising calorimeters and give a value of 6324 calories per gram at 15° C. White[7], however, prefers electric heating for the calibration of heat capacity.

A useful modification of the Krocker Bomb is described by

* Published by the Institution of Petroleum Technologists. Price 6s. net.

[1] *Chem. Abs.*, 1923, **17**, 204.
[2] *Ind. Eng. Chem.*, 1923, **15**, 358.
[3] *J. Soc. Chem. Ind.*, 1923, **42**, 206A.
[4] *Ind. Eng. Chem.*, 1923, **15**, 1024.
[5] *Ind. Eng. Chem.*, 1923, **15**, 1075.
[6] *Chem. Abs.*, 1923, **17**, 318.
[7] *J. Wash. Acad. Sci.*, 1923, **13**, 17.

Bruhns,[8] the bomb being made of stainless steel and a sheet of Pt arranged above the capsule to prevent the flame impinging on the cover.

Parsons and Wilson criticise the Lovibond Tintometer in a paper entitled, "A New Method of Colour Measurement."[9] Complaint is made that the distance separating the two fields is against accurate colour matching; and also the colour scale is not additive. The Tintometer Co.[10] reply that it is doubtful whether the closeness of the fields is an advantage, but this arrangement can be obtained on their latest instruments if required. The use of any optical arrangement such as prisms is deprecated by this Company. They also state that the colour scale cannot be additive in one sense because of the law "that every definite substance has its own specific rate of colour development for regularly increasing thickness."

Mixtures of hydrogen and gaseous paraffins have always presented difficulties in gas analyses, but King[11] finds that the H and any CO can be removed selectively by combustion over copper oxide at 280° C., the paraffins remaining unchanged. Muller and Foix[12] allow 15 cc. of the mixed gases to react with palladium chloride at 50–60° C. for 7 days. H precipitates an equivalent of Pd which is filtered off, ignited to oxide and weighed.

H. T. Clarke and E. J. Rahrs[13] describe an efficient fractionation column, which can be made from laboratory materials.

Jæger[14] suggests a solution of boric acid as a means of removing unsaturated compounds. L. Losand[15] determines water content by means of reaction with sodium amalgam. The hydrogen evolved is either measured direct or in the case of high water content calculated from the rise in pressure.

The estimation of alcohol in benzol by extraction with water often leads to emulsions which can be avoided by first diluting with spindle oil and then extracting with a 5 per cent. salt solution, distilling and estimating the alcohol in the distillate.[16]

Jakes[17] uses cyclo hexane instead of light benzine for precipitating asphalt and claims thereby to get more consistent results.

A critical study of the methods of estimating sediment and tar

[8] *J. Soc. Chem. Ind.*, 1923, **42**, 866A.
[9] *Ind. Eng. Chem.*, 1922, **14**, 269.
[10] *Ind. Eng. Chem.*, 1922, **14**, 1169.
[11] *Fuel*, 1922, **1**, 103.
[12] *Bull. Soc. Chim.*, 1922, **33**, 713.
[13] *Ind. Eng. Chem.*, 1923, **15**, 349.
[14] *J. Soc. Chem. Ind.*, 1923, **42**, 967A.
[15] *J. Soc. Chem. Ind.*, 1923, **42**, 172A.
[16] *J. Soc. Chem. Ind.*, 1923, **42**, 706A.
[17] *J. Soc. Chem. Ind.*, 1923, **42**, 1059A.

value of oils has been made by A. D. Bauer,[18] and Casimer[19] respectively.

The determination of sulphur content is, perhaps, the most vexed question of oil analysis, this being undoubtedly due to the importance of knowing accurately the amount of this element present and the length of time necessary to carry out the orthodox gravimetric method. For this reason volumetric methods are most useful, but the sensitiveness of indicators still requires improvement. A number of methods have been put forward during the year, but these require the verdict of time before general adoption.

Hauser[20] absorbs the oil on cotton wool which is then placed in a burner consisting of two concentric vessels of quartz or platinum, the smaller vessel being perforated. The combustion takes place in a 12 litre bottle filled with oxygen immersed in water and the SO_2 absorbed in alkaline solution and determined in the usual manner. Hiller[21] burns the oil with a mixture of $KClO_3$ and Na_2O_2 in an iron crucible the lid of which is secured by clamps. After the reaction the contents are washed out and the sulphate determined in the usual manner.

The use of benzidine hydrochloride reagent has also been mentioned for sulphate determinations. Ter Meulen[22] has devised a combustion method, which consists in passing the vaporized oil with hydrogen over Pt quartz. The S is reduced to H_2S which is then determined idometrically, or in case of low sulphur content, colorimetrically. The method requires careful manipulation, but the results are extremely accurate to very minute quantities.

Cracking.

By R. PITKETHLY and A. E. DUNSTAN, D.Sc., F.I.C., F.C.S.

DURING the past year more attention than ever before has been paid to this most interesting development in petroleum technology. The commercial importance of the subject may be gauged by the production of cracked gasoline, during last year, in the United States of America. G. Egloff and J. C. Morrell[1] estimate that 2800 million gallons were manufactured, and an overwhelming proportion of this was produced by liquid phase processes.

[18] *Chem. Abs.*, 1923, **17**, 337.
[19] *J. Soc. Chem. Ind.*, 1923, **42**, 878A.
[20] *Chim. Ind.*, 1923, 231.
[21] *J. Soc. Chem. Ind.*, 1923, **42**, 134A.
[22] *Rec. Trac. Chim.*, 1922, **41**, 112.
[1] *Chem. and Met. Eng.* 1923, **29**, 53.

Out of the number of patents which have been filed for the production of light spirit from heavy distillates or residues only a few have reached the commercial stage, and the most noticeable feature in this section of the oil industry is the steady development of the so-called liquid phase processes, in which thermal decomposition takes place without the aid of chemicals or catalysts. Refiners favour simplicity of process and design of plant for practical reasons. Many patents lack these essentials, and for that reason stand condemned.

Vapour phase processes are more or less out of date, on account of the heavy loss, in the shape of gas and coke, accompanied by a poor quality of product. Also, their application is limited to the treatment of comparatively light distillates.

Other processes, on account of their novel features, have received attention, such as the impact process of V. L. Emerson[2], who claims that cracking is caused or aided by injecting the oil, at high pressure, into a suitably heated chamber, through opposed jets, at a velocity of 2900 ft. per second. It is asserted that the impact of the hydrocarbon molecules produces dissociation.

E. M. Hyatt[3] puts forward a process wherein the oil is cracked after treatment with chlorine. The gasoline produced is said to require only a treatment with caustic soda to make it suitable for the market.

Plauson[4] uses zinc chloride in his process, and states that the results are good.

T. Ulke[5] finds that sodium formate or the like produces hydrogen at high temperatures in a process of the Bergius type.

Tin and other alloys are made use of by Melamid[6] to assist hydrogenation of hydrocarbons at high temperatures. Absorbent materials such as activated charcoal form the basis of a process patented by S. J. M. Auld.[7] The process is carried out under a low pressure, and it is claimed that gas oil of initial boiling point 210° gave a yield of 70 per cent. of petrol boiling below 200° C. The spirit was of good colour and smell, and did not deposit gum on standing for a long period. When used with Persian gas oil substantial yields of naphthalene were produced at comparatively low cracking temperatures.

A. M. McAfee[8] and others have continued their work with aluminium chloride as a catalytic agent in cracking processes. The

[2] E.P. 163,277, 168,573.
[3] U.S.P. 1,445,688.
[4] E.P. 163,277, 168,573.
[5] U.S.P. 1,445,423.
[6] E.P. 171,367, 171,390, 174,321, 180,625, 193,922.
[7] E.P. 208,569.
[8] U.S.P. 1,476,091, 1,478,444.

distillate in Dr. McAfee's process is water white and only requires a soda wash to secure finished gasoline of pleasant odour, but the one inherent difficulty suggests itself—that of cheaply manufacturing and recovering the catalyst.

J. J. Jakosky[9] deals with the subject of electrical processes in his paper read before the American Chemical Society, and shows that claims cannot be confirmed regarding no coke formation, less unsaturation, or polymerisation of uncondensed gas, and that no hydrogenation takes place. Any other effects could be produced by using higher temperatures in the cracking zone.

I. L. Gray[10] injects the oil to be cracked through molten metal.

W. J. Waterman and W. J. Perquin[11] have tested the Bergius system of cracking under high pressures with and without hydrogen, and conclude that in both methods complete conversion of oil and gas occur, but products of lower specific gravity were obtained in presence of hydrogen than in the simple cracking operation. The Bergius method is considered by them to be superior to cracking without hydrogen under pressure, in that gasoline of superior quality is produced.

The processes of R. Cross[12], C. Ellis[13], J. C. Black[14], S. J. M. Auld, A. E. Dunstan and P. H. Herring[15] and others have been developed on the liquid phase system, wherein the oil is kept substantially in the liquid condition throughout the operation of cracking by means of pressure, and the deposition of the coke formed during the process is directed into special settling chambers, which are not directly fired or from which heat loss is prevented by heavy lagging.

Dubbs[16] has further developed and improved on the pressure distillation method of cracking to the extent of handling heavy residues, and has brought his process into prominence commercially. The Cross-Dubbs and Auld-Dunstan-Herring processes differ from the shell still pressure distillation processes of the Burton, Fleming, Jenkins, etc., type, mostly in the alteration of the heating and cracking zones, so that only a small quantity of oil is directly heated, and little or no coke is deposited in the cracking tubes, whereas in the older processes cracking and coke deposition took place in the same chamber. The use of shell still processes, requiring direct firing, is limited to distillates with low coke-

[9] *J. Inst. Pet. Tech.*, 1923, **9**, 266A.
[10] U.S.P. 1,474,147.
[11] *Proc. Acad. Sci. Amsterdam*, 1923, **26**, 226.
[12] U.S.P. 1,437,229.
[13] E.P. 174,089.
[14] U.S.P. 1,456,419.
[15] E.P. (Appl.) 4,924 (1923).
[16] U.S.P. 1,123,502.

forming properties, and there is the added fire risk on account of the large quantity of oil in the still during the process. The newer processes, on the other hand, have their reaction chambers (expansion chambers or reactors) lagged with insulating material or with waste gases to prevent heat loss and to maintain the cracking temperature, all the heat necessary for conversion being given in the tube furnace. The newer processes can deal with practically any kind of distillate; residue, or even heavy Mexican crude oil[17] can be successfully handled, and they have the advantage that smaller proportions of gas and carbon are produced. The refining of the cracked product is also a simpler matter, owing to the limited formation of highly unsaturated compounds.

A great number of processes, with and without novel features, have been patented, but most of these have not reached the large scale stage, and probably never will; but they serve to indicate the extent to which research work is being prosecuted in the endeavour to obtain a perfect cracking process and the amount of time and money expended on the subject.

Liquid phase processes of the simplest nature only have been developed into commercial proportions, and particularly two outstanding processes of this nature are the Cross and the Dubbs processes. In the Cross process a comparatively high pressure is used to maintain the oil substantially in the liquid phase under the conditions of temperature employed in the process, and the Dubbs process working under a much lower pressure, and in nature, more of a pressure distillation but without many of the disadvantages of the older pressure still type of cracking processes such as the Burton, Jenkins and Fleming. The newer process of Auld, Dunstan and Herring produces similar results, but the necessary heat is applied in three distinct zones and no decomposition takes place in the tubes in the firing chamber.

These three processes are more or less typical of the liquid phase processes which seem at the moment to be characteristic of the present condition of our knowledge of the subject.

The originators of the Cross process more than thirteen years ago started experimental work, initially on vapour phase cracking, but ultimately came to the conclusion that the correct method of pyrolysis was the application of heat to the oil in the liquid phase. They state that in order to do this it was necessary either to maintain the high pressure of the vapours on the liquid or to reflux the undecomposed oil with loss of heat and consequent retardation of the rate of conversion. It was soon established that a pressure should be maintained at the cracking temperature which would effectively prevent undue vaporization.

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[17] G. Egloff, *Nat. Pet. News*, 1923, **15**, 12.

After these basic principles of operation had been evolved efforts were made towards the production of a commercial plant of simple design but of specially robust construction. A failure in any part would mean disaster, and many failures had happened in plants of the pressure distillation type, working at comparatively low pressures but with a large amount of oil in the still. The method of continuous operation was therefore adopted, and heat is applied to the oil in tubes 24 ft. long, 3 ins. internal diameter, and ½ in. thick, arranged in a specially constructed furnace. The tubes are in two banks, with 45 tubes in each (these dimensions vary, according to the size of the plant) arranged horizontally in series forming continuous coils. The oil is pumped downward through the upper or preheating coil and upward through the lower or cracking coil, and it is claimed that little or no decomposition takes place in the coils, at any rate sufficient to deposit carbon, although the oil attains a temperature of about 470° C. as it leaves the cracking coil. A pressure of about 600 to 700 lb. per sq. inch is maintained in the system, varying with the kind of distillate under operation.

From the coils the heated oil is passed directly to the reaction chamber, wherein the conversion of the heavy oil into gasoline is completed and carbon is deposited. The horizontal reaction chamber, 40 ft. long, 38 ins. internal diameter, and 3 ins. thick, is forged from a steel ingot without welds or riveted joints.

No heat is applied to the reaction chamber, but it is heavily insulated to prevent loss of heat. No distillation is allowed to take place in the reaction chamber, as this would have a cooling effect and retard conversion. The oil is held in this chamber for a sufficient length of time to establish equilibrium between liquid and vapour phases, and this period is estimated to be about fifteen minutes.

A control valve is set at a predetermined level; coke is deposited in the reaction chamber, and the oil passes out to a vapour separator, where a certain amount of fuel oil is collected. The vapours then pass to the dephlegmator. The column efficiently separates the spirit from the heavier uncracked fractions, which are returned for re-running through the cracking tubes along with fresh oil.

Sufficient gas is generated in the process to provide fuel for the entire cracking operation. Extra fuel is required for preliminary heating amounting to about 1 per cent., which, including the gas, makes a total of about 6 per cent. The loss due to coke is of the order of 1 per cent., and varies of course with the nature of the cracking stock.

The same plant will operate on kerosene, gas oil, or distillate fuel oils, but it is recommended that heavy fuel be first distilled (an apparatus can be obtained for the purpose with the plant), and

the distillate only be used for cracking, as fuel oils deposit a greater quantity of carbon than distillates, consequently shortening the length of time that the plant will remain in operation.

The plant must be shut down periodically, about once per week with gas oil and every 20 days or so with kerosene stock, for cleaning out the coke, but before doing this steam is injected through the coils and reaction chamber in order to distil out the oil, cool the plant, and at the same time render the coke brittle and more suitable as a fuel.

It is stated that a 33 per cent. yield of navy gasoline can be obtained in one cycle from gas oil, 39 per cent. from kerosene, and 20-25 per cent. from fuel. Units can now be made to deal with a throughput of 2000 barrels per day, and recently such a plant, which is stated to be functioning satisfactorily, has been erected in England.

It is reported that up to date 3,000,000 barrels of oil have been cracked by the Cross process, and seventy installations are now in use.

The Dubbs process has reached a stage of development where not only gas oil but heavy fuel oils have been cracked successfully. The commercial success of this process may be gauged by the fact that more than 100 units of 500 barrels daily capacity are in operation or under construction, producing at the rate of about 300,000,000 gallons of gasoline per annum.

It is reported that gas oil, fuel oil, topped oils and low grade crude are running directly through the plant, yielding an average of 40 per cent. navy gasoline in one cycle, and that kerosene distillates give more than 50 per cent. of the same product.

The inventor claims that the weaknesses of vapour phase, catalytic, and direct fired distillation processes, using low pressure on the one hand, and high pressure tube and chamber type processes on the other hand, are absent in his process.

Limitations are imposed on the latter type owing to the choking of outlets, and the somewhat meagre provision for the storage of coke, and on the former owing to high loss and fuel consumption in the vapour phase, cost of catalyst or its recovery in catalytic processes, and the fire hazards of the pressure still.

In the entire working system of the Dubbs plant the total amount of oil present at any one time averages about thirty-five barrels only. This, contrasted with 200 to 350 barrels as in shell type of still, gives a high safety factor with regard to fire hazard.

A standard Dubbs unit, 500 barrels daily capacity, consists of a side fired furnace having two compartments, one for firing and the other for heating the coil of tubing, composed of fifty lengths of cold drawn seamless steel tubes 4 ins. in diameter and 30 ft. long,

connected in series. Aluminium bronze plugs are used in the return bends of the coil for cleaning and inspection.

The double furnace is designed so that the tubes are not directly exposed to the furnace flame, but receive heat from the hot gases only.

The raw oil, preheated by the returned oil from the dephlegmator, is pumped through the furnace coil, where it attains the temperature necessary for cracking. It leaves the coil at an average temperature of 450° C., passes directly into the expansion chamber, which acts as a reservoir for coke and coke-forming substances, and the unvaporised residual oil is drawn off from it continuously. The chamber is an upright cylinder of hammer-welded steel, 10 ft. in diameter and 15 ft. high, provided with manhole doors at top and bottom for cleaning out the coke, and means for drawing off the heavy oil.

No heat is applied to the expansion chamber, but it is heavily lagged with insulating material to maintain the temperature imparted to the oil in the cracking coil. This eliminates danger due to overheating. The cracked vapours pass from the expansion chamber through a vapour line to an elevated dephlegmator, where the fractions are condensed above the gasoline limit and allowed to run back into the feed. The uncondensed light vapours are water cooled, and the uncondensable gas is separated while the pressure distillate is stored for further redistillation and refining into a marketable product.

The average temperature at the bottom of the dephlegmator is about 395° C., and the condensate preheats the ingoing oil to about 300° C.

Part of the cracked distillate may be pumped back into the top of the dephlegmator, in order to control the boiling range of the cracked gasoline.

An alternative method of controlling the temperature is to pass a portion of the raw feed, instead of pressure distillate, into the dephlegmator.

The pressure on the system, about 120 lb. per sq. inch, is controlled by a needle valve at the outlet, so that the operation of the plant is simple and the labour cost low. The permanent gas produced is used as fuel in the furnace. At the end of each run steam is passed through the coils and expansion chamber, after draining the plant, in order to dry the coke and render it brittle.

The coke is broken up by means of a chain round which the coke forms. The chain is pulled by a power hoist and the coke drops out through the bottom manhole.

The duration of each run, which varies with the type of oil to be

cracked, is limited only by the capacity of the expansion chamber for the storage of coke.

On different classes of heavy oil ranging from Louisiana fuel to Panuco crude the yield of navy gasoline amounted to from 24 to 44 per cent., with a coke production of 3·8 to 15·2 per cent. The process is extremely flexible, as any oil from kerosene to heavy Panuco crude fuel oils can be handled.

The cracked product varies with the quality of raw stock, but a general method of refining can be used for all types of cracked distillate. Dubbs recommends the following :—

1. A water or dilute alkali wash.
2. Plumbite treatment.
3. Water acid followed by 3 to 10 lb. per barrel of 66° Bé sulphuric acid per barrel.
4. Water and caustic soda wash to neutralise.
5. Redistillation.
6. Final soda wash.

The residual fuel drawn from the expansion chamber has low cold test, low viscosity, and high calorific power.

The fuel consumption in the process ranges from 6 to 12 per cent. of the throughput.

The Auld, Dunstan and Herring process, while of general application, is of special utility in the treatment of heavy residues to obtain from them a limited proportion of light spirit and to render the residue after removal of the light spirit less viscous and more suitable as a fuel oil than before.

It has among its objects : to avoid secondary reactions in the vapour phase, to reduce the amount of uncondensable gas, to obtain products of good quality and to restrict the quantity of light products, so that the vapours or gases are in large measure dissolved in the treated residue forming a liquid, in which part of the carbon produced is carried away, while the carbonaceous matter deposited is relatively small in quantity and is not deposited on the " thermalising " tubes, where it would choke and hinder the operation, but is exclusively deposited in the " reactor " in such a state as to be readily removed.

The essential parts of the plant consist of feed tank, pump and a preheater connected to a casing or header, into which the oil flows. To this casing the bottom ends of a number of vertically placed short heating, or " thermalyser," tubes are connected, and their upper ends enter the " reactor," a cylindrical steel vessel of large capacity.

The capacity of the reactor is determined having regard to the rate of flow through the thermalyser tubes and to the maintenance of the liquid in the reactor for such a length of time that the

required extent of cracking is completed, usually within two hours. From the reactor the cracked oil flows through a cooler and relief valve into a gas separator. The oil is continuously fed into the apparatus and continuously withdrawn from the reactor.

The furnace is specially designed to give complete control of the application of heat in three distinct heating zones—*i.e.*, the preheater, the thermalyser and the reactor, in order to keep the temperature of the furnace gases at the minimum required to provide the necessary heat in the different sections, without overheating any particular part, in such a manner that the oil in the preheater is heated to a point definitely below cracking temperature, in the thermalyser to a determined temperature above the mean cracking temperature, and in the reactor it is maintained at the mean cracking temperature. Thus the liquid is first preheated to within a determined limit of the temperature of cracking; for example, to within not less than 25° C. of that temperature. It then flows upwardly at a relatively low velocity through a number of thermalysing tubes of short length, 10 to 15 ft. and of small diameter, and subjected to heat, applied uniformly and gradually. The heat is applied under conditions in which a gas lock is avoided and in which none of the liquid is heated appreciably above the temperature of the remainder, so that the cracking reaction is not liable to be propagated prematurely, and cause carbon to be deposited within the thermalyser tubes. By reason of the method in which the heat is applied, the interval between the acquisition of the cracking temperature and the consequent reaction is prolonged, and advantage is taken of this prolongation to raise the temperature of the oil beyond the mean temperature at which cracking is effected in the reactor. It has been found in the use of thermalysing tubes that a final temperature of about 20° C. above the mean reactor temperature may be used, but different oils require different conditions of temperature.

There is within certain limits a definite time temperature ratio corresponding to determined yields of spirit for each hydrocarbon oil which may be treated by the process. The lower limit is specific for each, but in general is not lower than 350° C. nor higher than 400° C., and lower for heavy hydrocarbons and higher for light oils.

The products of cracking are as far as possible maintained in the liquid condition, and the total yield of light products and unsaturated hydrocarbons are limited under relatively low or moderate temperatures of cracking, although the process may be employed in securing higher yields.

The time factor may be varied by alteration of the rate of flow, and the determined mean temperature may also be varied within restricted limits.

The oil is continuously fed through the apparatus and continuously withdrawn, so that the operation is only brought to a finish when a sufficient amount of carbonaceous matter has accumulated in the reactor to interfere with the proper working of the process, when it is discontinued and cleaned.

The process is advantageously carried out under such conditions as to produce a relatively small quantity of gasoline. For example, in the treatment of heavy or fuel oils 10 to 15 per cent of gasoline may be produced, while from other stocks a higher yield may be secured but substantially less than the yields possible in the employment of higher temperatures and pressures than those contemplated in carrying out the process. These moderate conditions of working will produce a lower percentage of petrol in each cycle, but the plant should run a correspondingly longer time and with a loss which is definitely less in proportion to the throughput.

Carleton Ellis also uses a combination of tubes and reactors, built in 2000-barrel units. The oil to be processed is fed into the tube system at 350 lb. pressure and passes at the rate of 5000 gallons per hour. It is next received into vertical reaction vessels —"soaking drums"—in which the same pressure is maintained. The quality of the synthetic crude fixes the time needed in the drums. Usually the product is released steadily and passes into horizontal vaporising stills; thence into a fractionating column. The flexibility of the plant is increased by the provision of two reactors per heating coil. These can be operated singly or in pairs, or if merely a heat treatment for viscosity lowering is needed they can be by-passed entirely. The convenience of operating one reactor whilst its fellow is being decarbonised is obvious. An average six-day cycle is run on gas oil. By provision of efficient heat exchangers the feed oil enters the coils at 450° F.

Refining and Refineries in 1923.

By J. McConnell Sanders, F.I.C., F.C.S.

The year 1923 was remarkable for the extraordinary crude oil situation in the United States, and for the far-reaching effects which this had, not only upon refining operations and market conditions in that country, but also for its retroactive consequences in other fields of activity.

While production in Mexico had steadily declined, nearly every other producing field had shown increased output as compared with 1922, and in the United States several causes had contributed to stimulate activity to an unprecedented degree.

The inherent idea of a possible shortage provoked by widespread propaganda, the consequent influx of new capital, and the simultaneous improvement in technique, whether in oil-winning or in refining, had all coincided in their effects with those produced by the active crusade against waste, which had been initiated by governmental centres five years previously.

In some fields the grading of crude oil on intrinsic value instead of on a gravity basis had considerably affected refinery methods, and when it was realised that low-grade crudes could be handled profitably by improved methods, a retarding effect was brought about upon the demand for lighter crudes, and this led to over-production. Actually the rate of increase, which in the period 1907–1919 was 7·1 per cent., in the next four years rose to 16·1 per cent. per annum.

In California an enormous flush production reached a maximum during July, when for about a week it totalled 875,000 barrels daily.

In spite of this the mid-continent fields recorded the greatest year in new production of any in the history of American oil production, with 23,453 new wells, of which 15,327 were productive, 2319 were gas wells, and only 5807 were "dry holes."

California was unable to refine all its production, and it was actually found profitable to ship oil *via* the Panama Canal to eastern refineries for treatment, where more profit was made by the latter than could have been realised in California itself.

This Californian crude served to replace the Mexican oil which had formerly supplied Atlantic and Gulf Coast refineries, but the turn of the tide for Mexico took place quite early in the year, when on February 22 the first Eagle tanker left Los Angeles with a cargo of 120,000 barrels of Californian crude oil to be refined by the Mexican Eagle Oil Company in their refinery at Tampico.

The United States Refinery statistics for 1923 provide some interesting figures, which may be briefly summarised in the following table :—

PERCENTAGE INCREASE OR DECREASE PRODUCTION OF REFINED PRODUCTS IN 1923 AS COMPARED WITH 1922.

	Gasoline.	Kerosene.	Gas Oil and Fuel.	Lubricating Oils.
	%	%	%	%
New production plus imports	+23·67	+1·85	+16·25	+12·21
Consumption plus exports	+26·64	−0·82	+14·03	+13·72
Stocks at end of year	+21·62	+0·71	+13·88	+ 2·99

It will be noticed that in none of the products mentioned did the stocks at the end of the year show an increase commensurate with the increment in total consumption.

It is further stated that at the end of the year 246 refineries were reported as operating to the extent of 76·61 per cent. of the aggregate capacity, running to stills a daily average of 1,653,195 barrels of crude oil.

Compared with statistics for 1922, it is noteworthy that refining losses were slightly lower, and the average yield of light products somewhat higher, while at the same time there was a decided increase in the proportion of casing-head gasoline recovered and utilised to blend with heavier spirit. Although at the end of 1922 there were 311 refineries reported as operating, with a combined capacity of 1,900,560 barrels daily, thus showing a decrease apparently for the year under review, many of these had ceased to operate, and actually a number of new refineries were completed and started up in 1923 owing to the increased demand, one of the largest being built by the Pan-American Company near Los Angeles, with a daily capacity of 50,000 barrels.

The fuel oil situation was also somewhat remarkable, the production being 11·5 per cent. over that for 1922, or about the same as the increase of 1922 over that for 1921, but the consumption was only 5·5 per cent. greater than that for the previous year, or about one quarter of the increase shown for the 1922–1921 period.

In the mid-continent fields railway contracts for fuel oil were closed at 90 cs., or better when crude oil fetched $1·25, so that refiners could well afford to take less for their light oils, a fact which reacted on the market generally.

In Mexico the refining situation had got steadily worse since the decline in light crude production in 1922, prior to which there were about 17 refineries or topping plants in operation, with about 473,000 barrels daily capacity. In 1923 only four companies were carrying on seriously, the distribution of their operations being approximately as follows :—

	%
Huasteca	56
Aguila	31
Corona	7
Texas	5
Miscellaneous	1

Out of six topping plants established at Port Lobos, all except one ceased operating, owing to the salt-water developments in the Amatlan and Zacamixtle fields. Of the Tampico plants the only ones left in operation were the Aguila, Corona, and Pierce Oil Refineries ; the Pierce Oil Refinery at Vera Cruz was shut down in 1922.

The notable exception to the above story of shut-downs or reduced capacity among refineries is that of the Huasteca Company,

which not only maintained and even increased its throughput; but accelerated construction work on new gasoline plant at Tampico in September last, to have a daily capacity of 840,000 gallons, at an estimated cost of $2,400,000 U.S.

In March Panuco crude for the first time went ahead of light southern crude production, and by a steady stream of new producing wells now represents about 70 per cent. of the total Mexican production.

With regard to refining methods generally, it is noted that the vigorous campaign against wasteful methods carried on by the United States Government had considerable influence both in oilfield and refinery practice, and the year was prolific in new inventions, having economy and conservation of material as a predominating feature. Want of space precludes any but a very brief survey of these.

Distillation.—The tendency to utilise tubular stills and separators of the Trumble type, instead of the more cumbersome cylindrical still, is increasing, and the avoidance of distillate re-running, with its consequent loss and expense, is secured in many refineries by the inclusion of more efficient dephlegmating or fractionating devices in their installations. Perkins (U.S.P. 1,444,208) has patented a new form of dephlegmator in which uncondensed vapours are washed by condensate which is subsequently cooled to the "dry point" of the spirit to be obtained. Black (U.S.P. 1,447,118) has a somewhat similar device, his fractionating tower being divided into compartments in which vapours are washed with oil of the same physical nature as the heavy fraction to be eventually separated.

A somewhat novel form of still is proposed by W. W. Witt and the Stirling Boiler Company (Br. P. 191,465) in which some of the features of the well-known Stirling steam boiler are included, a more efficient heat transfer being claimed.

One of the difficulties frequently met with in the practical use of tubular heating systems has been the tendency for the tubes to burn out rather easily, either from too intense local heating or from interruptions in the oil circulation. A remedy for this has been provided by the introduction of so-called "calorised" steel tubes, in which by a special method the surface of the steel is alloyed with aluminium. Such calorised steel is also claimed to be very resistant to corrosive influences. (A. V. Farr, Chem. Met. Eng., 1923, 29, No. 27, 1188.)

The utilisation of still gases, and the recovery of gasoline therefrom, has attracted more attention than was formerly the case, and according to Dow, of the U.S.A. Bureau of Mines, as much as

30 gallons of gasoline per 1000 cubic feet may sometimes be obtained, the general average being 7 gallons. Actual experiments in some typical refinery installations showed a recovery of from 0·44 to 1·0 gallons of gasoline recovered per barrel of crude charged to the stills. According to W. Traube and R. Justh (Brennstoff-Chemie, 1923, A. 150) the absorption of ethylene from gaseous mixtures is more effectively carried out by chlorsulphuric acid than by sulphuric, even with rapid currents of gas. Hence the preparation of ethyl chlorsulphonates from waste gases can eventually lead to the preparation of ethyl alcohol by treatment with water.

Treatment.—The purification of petroleum products by the drastic and wasteful method of treatment with sulphuric acid, although one of the oldest methods, has for long resisted the attempts by refinery technologists to provide an efficient substitute. The year under review, however, has shown decided progress towards the achievement of this desideratum, although many of the methods brought forward were conceived many years ago, and only after improvement or modification became capable of application on a commercial scale. The use of chlorine for refining, and more especially for desulphurising white oils, was made practicable by Dunstan (Br. P. 139,223/18, 184,281/21, 204,078/22), and the method is now being used both in this country and the United States.

Arnold (U.S.P. 1,454,593) proposes to desulphurise, and at the same time convert the sulphur into a marketable product by treating the oil with liquid, anhydrous ammonia in the presence of a catalyst and an oxidising agent. Ditmar (U.S.P. 1,448,643) claims to be able to desulphurise by heating the oil with a metallic soap.

The use of adsorptive agents such as silica-gel, iron gel, bog iron ore, as well as the older reagents, bauxite and Florida earth, has again come into prominence, and particularly the first of these has now many advocates, not only for decolorising, but also for desulphurising and the removal of aromatic hydrocarbons from kerosenes. Dunstan and Thole (U.S.P. 1,457,656) claim the application of dehydrated natural or artificial gels while still warm after recent ignition. Clemons (U.S.P. 1,449,734) supports a layer of the adsorptive material on a shelf inside a still, so that oil vapours have to pass through it. Some experiments by E. R. Inman (*Oil & Gas Journal*, Vol. III., 34, 92) showed that bog iron ore possessed excellent decolorising properties, being more efficient than fuller's earth in the ratio of nearly 2 to 1.

A somewhat novel method for desulphurising is claimed by Smith (U.S.P. 1,450,617) who saturates cotton-waste with a

strong solution of alkali, and heats this with the oil under a pressure of at least 100 lb. for 3 hours.

In the treatment of lubricating oils the prevention of emulsions is proposed by Ayres (U.S.P. 1,454,617) who claims the addition of a soap, soluble in the oil. This recalls the process of Delbridge (U.S P. 1,438,985), who treats paraffin wax before sweating with a soap solution, in order to remove colloidal material and obtain large crystals of uniform size. Johansen (U.S.P. 1,438,764) also claims the use of soap in aqueous solution for washing lubricating oil stock to render the latter non-emulsifying and improve the colour.

The Edeleanu process for treatment with liquid sulphur dioxide, which was originally better known as a means for removing aromatic hydrocarbons from kerosene distillates, is now receiving considerable attention for the manufacture of paraffin wax and lubricating oils, for which purpose it appears to have specially valuable features, under modified methods of operating.

For deparaffining, Erdmann (U.S.P. 1,443,983) claims the use of acetone as a means for separating wax from tar, avoiding the necessity for distilling the latter. Greenspan (Br. P. 203,098) separates amorphous wax from the crystalline variety in viscous paraffin oils, by diluting the latter with kerosene at ordinary temperatures, so as to precipitate the crystalline wax. After removing the latter by filtration the filtrate is distilled until the residue is free from amorphous wax. Hapgood (U.S.P. 1,464,707) continuously separates wax from lubricating oils by successive refrigeration, followed by centrifugal treatment. The first chilling being effected by a system of cold exchangers, the second by the direct expansion of ammonia gas.

Centrifugal methods generally have been greatly improved and are being used for a variety of purposes in modern refinery practice. The separation of wax from chilled paraffin oil is described by L. D. Jones (Amer. Inst. Min. & Met. Eng., Oct., 1923), who experimented with new methods of applying a carrier liquid (chilled brine) by means of a jet directed within a ring on the rotor of the centrifugal machine. The centrifugal separation of acid sludge from viscous lubricating oils is stated by E. E. Ayres to be facilitated by agitating the sour oil with 0·1 per cent. of starch, neutralising with dilute soda, and then adding water.

Cracking.—The general diminution in supplies of light crudes and the ever-increasing demand for gasoline has made the conversion of heavy hydrocarbons into lighter ones an economical necessity. It is estimated that in 1923 about one-third of the total production of gasoline in the United States was obtained by cracking. The number of patented processes continues to increase, and the

literature referring to this subject alone would fill volumes. There were few outstanding novelties, however, published in 1923. The old problem of dealing with carbon formation was solved by variations of what is commonly alluded to as the "tube and tank" process, the heating of the oil being carried out in a pipe still, the deposition of carbon being allowed to take place in a separate vessel, which was not exposed to direct heat. Nevertheless, a few processes were patented in which carbonaceous deposits were removed by some form of mechanical device. Among older methods now being exploited in improved or modified forms may be mentioned that of Dubbs, between whom and the owners of the Burton patents there is still pending litigation regarding priority of invention. Methods involving the use of molten metal as a heating medium have been patented by Gray (U.S.P. 1,474,147), who injects oil into the lower ends of a series of tubes filled with molten lead; while Watson (U.S.P. 1,474,395) circulates the molten metal through a nozzle inside a still, the oil being injected into the stream of metal as it issues from the nozzle. Hoge (U.S.P. 1,474,475) cracks in the vapour phase in tubes which are immersed in molten lead.

Among high pressure systems that of Black (U.S.P. 1,456,419) operates at about 1050 lb. per sq. inch, which is the highest pressure of any commercial process; that of Cross (600 to 800 lb.) being next in order, while all other pressure systems utilise from 90 to 120 lb. only. As in the Cross process, Black's method involves high pressure for the actual cracking stage, but unlike Cross, he does not permit vaporisation to take place until the oil has left the cracking zone, and carbon is separated while still held suspended in a liquid medium. It is claimed for the product that it is similar in character to a straight-run distillate, and that the cost of manufacturing gasoline does not exceed 6c. per gallon, with crude oil at $1·00 per barrel.

Similar claims are made for the process of Schwarz (U.S.P. 1,458,443), in which a still and double tower is filled with steel turnings, and the process is so conducted that unsaturated, high-boiling hydrocarbons are brought into contact with saturated, low-boiling vapours, while the necessary temperature regulation is secured by circulating cooled reflux oil from a dephlegmator in and out of the still by means of an injector.

A somewhat novel method is patented by Hyatt (U.S.P. 1,445,688), who passes chlorine into oil and then heats under pressure, while Lasher (U.S.P. 1,457,068) claims to produce cracked products by heating oil with common salt.

As regards the refining of cracked spirit, Remfry (Br. P. 205,868) has patented a process for treating in the vapour phase with dense

activated charcoal, whereby the compounds which cause gumming are said to be polymerised.

Hydrogenation processes attracted considerable attention during the year, that of Bergius, which was published several years previously, being often referred to in the literature. Although it is stated that a large commercial plant was operating at Rheinau, the details regarding the results obtained are not available, and it would seem that the initial difficulties encountered in large scale working have not been entirely overcome. Rostin (U.S.P. 1,451,052) passes hydrocarbon vapours, together with a substance containing hydrogen, over a substance capable of splitting off hydrogen from the latter. For instance, a mixture of unsaturated hydrocarbons and hydrogen sulphide may be passed through heated tubes containing copper turnings, when the reactions represented by the following equations take place :—

$$(a)\ H_2S + Cu = CuS + 2H$$
$$(b)\ C_nH_{2n} + 2H = C_nH_{2n+2}$$

Fischer and Tropsch (*Brennstoff-Chemie*, Sept., 1923) describe the production of a synthetic motor spirit from hydrogen and carbon monoxide, which appears to have great possibilities. Their method entails first the low-temperature carbonisation of coal, the resulting semi-coke being then converted into water gas, which is essentially a mixture of carbon monoxide and hydrogen. After purification, the mixed gases are passed into a tubular apparatus where they are subjected to a pressure of about 2000 lb. per sq. inch, in the presence of iron turnings coated with a catalyst such as potassium carbonate. The resulting vapours on condensation yield a watery solution and an oily liquid which consists mainly of higher alcohols up to $C_9H_{15}O$, and this liquid constitutes the synthetic motor spirit to which the name of "Synthol" has been given.

When synthol is heated under pressure it may be converted into a mixture of hydrocarbons, almost free from oxygen, with the odour and properties of petroleum, to which the name of "Synthin" has been given.

Forwood (U.S.P. 1,440,286) also combines water gas production and hydrogenation by passing steam and oil vapours over heated carbon. He states that by keeping the temperature at or below 600° C. it is possible to decompose the steam without decomposing the oil.

Miscellaneous.—Lentier (U.S.P. 1,473,350) claims that selenium oxychloride reacts with unsaturated aliphatic hydrocarbons and with aromatics, but does not attack the paraffins. R. Schonfelder (*Ber. Ges. Kohlentechnik IV.*, 247–263, 1923) describes the pre-

paration of formaldehyde by passing a mixture of methane, steam and air over copper or silver heated to 500° C. The McAfee process for treating oil with anhydrous aluminium chloride has been the subject of several patented improvements. Prichard and Henderson (U.S.P. 1,476,219) claim a method of circulating the mixture of oil and catalyst, under optimum temperature conditions for maximum effect. McAfee (U.S.P. 1,476,091) claims a kneading method for dealing with the gummy mass formed in the stills when employing his process. The still contains steel balls, and a device for lifting them as well as stirring devices. Owen (U.S.P. 1,460,110) proposes to recover aluminium chloride from the mass left in the still by spraying it upon a hot surface so as to volatilise the salt. Stewart (U.S.P. 1,464,373) claims a method of separating coke from the still residues by first oxidising the carbon completely, and thus liberating the occluded aluminium chloride, which is converted into the oxide and chlorine, further heating in a reducing atmosphere regenerates the chloride.

Progress at Agwi Petroleum Corporation's Refinery, Fawley, Hampshire, during 1923.

By J. McConnell Sanders, F.I.C., F.C.S.

During 1923 considerable additions have been made to the already existing plant at Agwi Petroleum Corporation's Refinery, situate on Southampton Water, at Fawley, Hampshire.

Crude Distillation Plant.—An additional distillation unit based on the Lodge-Tinker cracking process has been erected, with a nominal capacity for treating 2000 barrels per day of light Mexican crude. This plant has been put up to embody the experience gained on the experimental plant built in 1921. The experimental plant has a capacity of 700 barrels per day, making a total throughput for cracking of approximately 2700 barrels per day. The new Lodge-Tinker plant has proved much more efficient than the original unit, and has been in operation from July 17 continuously until December 31, when the plant was still working completely satisfactorily. The plant, as at present arranged, could be used for topping crude oil, or for topping and cracking combined. When the plant is operated on topping alone, the throughput can be considerably increased. The plant is capable of continuously topping and cracking for the manufacture of petrol, white spirit, gas oil and fuel oil, and it has been possible

to use this plant for the distillation of various classes of crude, including Mexican, Persian, and Californian crude oils.

Steamstill Plant.—On January 8 a new battery of steamstills was put into operation, and these have been working continuously throughout the year and have given every satisfaction. The stills are combination stills and can be used either bottom fired or steam heated, and are thus able to be used for a larger variety of products which require re-distillation.

Treating Plant.—During the year the main agitator plant has been completed, and consists of three agitators, two of them having a charging capacity of 40,000 gallons, and a small one of 10,000 gallons. Two of these agitators are of the Typhoon type, and one is reserved for heavier distillates, and agitation is effected by means of compressed air.

Pumping Plant.—The main central oil pump house, with its complement of pumps, has been completed, and consists of two sections :—

(*a*) Black oil pump room with its manifold.

(*b*) White oil pump room with its manifold.

All the pumping of the refinery such as transferring to storage, loading and discharging vessels, filling agitators, etc., is regulated from this central pump house. The only pumping which is not done in this building is the pumping to various plants for regulating throughputs, and that is done in the pump room existing at the bottom floor of the receiving houses of the plants concerned. All the pumps, both black oil and white oil, in the central oil pump house are electrically driven. The black oil pumps handling crude oil, fuel oil and gas oil are of the rotary type ; the white oil pumps are triplex plunger pumps. There is only one steam pumping set in this building, which is for the supply and regulation of fuel oil to be used on the stills about the refinery.

Receiving Houses.—Each distillation unit has its own receiving house, which consists of a two-storey building.

On the bottom floor all pumps required to regulate throughput and pump-out stills are situated. All these pumps are steam Duplex pumps working against a 40-lb. back pressure, the exhaust steam being used in the process. The top floor of the receiving house contains the look boxes and distillate run down manifolds, and the distribution of the streams into the various receiving tanks is effected in this building. The pump-man in charge of the pump also controls the streams on the top floor.

The above gives the main outline of the more important additions to the existing plant which have been carried out during the year.

National Oil Refineries Limited, Llandarcy, Skewen, South Wales, during 1923.

By A. M. O'Brien, F.I.C., F.C.S.

Considerable additions have been made here, and in the Swansea Docks jetty extensions have been put into hand to afford greater facilities to cope with the increased traffic, average imports now being over 1,500,000 tons per annum, the bulk of which is re-exported coastwise. Consequently, something in the nature of 3,000,000 tons of oil are now passing through the Swansea Docks annually. Extra pipe-lines have been laid down, so that each class of oil can have one or more pipes allocated to its service.

Among the crude distillation units, additional plant of 1000 tons capacity daily has been erected, and is in full operation.

Obviously, extensions of this character necessitate adequate extension of auxiliary plant.

A new benzine redistillation unit has been erected, and is now running full capacity. This plant has a capacity of 18,000,000 gallons monthly of raw spirit, capable of producing approximately 1500 tons per day of petrol.

In connection with this, a washery and tankage have been built commensurate with the requirements of so large a throughput. The washers are of 50,000-gallon capacity, the agitation being secured by centrifugal pumps in a separate pump house, one for each washer. This arrangement is with a view to minimising fire risks.

A reservoir, capable of holding 90,000,000 gallons of water for circulating purposes, has been constructed in connection with the refinery generally.

With regard to the use of Bauxite for refining purposes, enormous strides have been made within the last twelve months, and it is possible that the time is approaching when Bauxite will be considered the principal refining agent in the petroleum industry.

A liquid SO_2 Treatment Plant of 200 tons capacity, has been erected, and is in full operation, for the refining of the lubricating oils which the Anglo-Persian Oil Company, Limited, is preparing to place upon the market, and also for the refining of various other products particularly amenable to this treatment.

In addition to this, there is a SO_2 Manufacturing Plant to supply liquid SO_2 for the purpose explained.

There is also completed and in full operation a Calcium Hypochlorite Manufacturing Plant using up not less than 15 tons daily of liquid chlorine for the manufacture of bleach solution used in the refining operation.

The Tank Farm has been increased enormously, the total storage capacity alone in this refinery now exceeding half a million tons, or some 140 millions of gallons.

The Scottish Oil Industry.

THE publication of the reports of the Scottish Oil Companies for the financial year which ended with March, 1924, showed that the twelve months had been a trying time, due to the low prices of products which prevailed, the effect of which was that for the larger part of the year the industry was operating at a loss. Adjustments, however, were made in all possible directions to reduce this loss, and the net result on all operations was that Scottish Oils, Ltd., was able to pay one-half of the preference dividend. The most notable event of the year was the completion of the new refinery at Grangemouth, which is to handle imported petroleum. This refinery, after a short period of experimental running, is now in full operation, and the results will be seen in the current financial year. The plant, which includes a berth for tankers drawing up to 30 ft. of water is, in many respects, an interesting departure from the traditional practice of the Scottish Shale Industry, a notable feature being the size of the crude stills, which are probably the largest in operation anywhere, being 36 ft. long as against a maximum length of 30 ft. reported for recent American stills. Treatment with hypochlorite and bauxite also supersedes the more usual sulphuric acid process. As Grangemouth is within twenty-five miles of both Glasgow and Edinburgh and well situated for sea transport to the Continent, the site of the new refinery is very favourable.

The refining of Persian oil has been continued at Uphall and the development of this plant for working up the crude to a fuller extent is now in hand. An 8-in. pipe-line is also being laid on a route fourteen miles long, to connect Grangemouth with Uphall, which will give considerable economy in transit charges on crude oil as compared with the railway transport hitherto used.

In the shale industry itself, there have been no special developments, operations having been conducted on the usual lines, but with intensified regard to economical working.

The Burmah Oil Company

BY JOHN GILLESPIE, M.I.Mech.E.

During the past months the most interesting features of operation on the fields of the Burmah Oil Company have been the completion of Field's Electrification Scheme, the introduction of the rotary method of drilling upon a more extensive scale and the attention which has been given to the importance of core taking

during prospecting work. Considerable success has accompanied the use of the rotary method both under steam and under electrical operation. It has been proved in certain instances that a high drilling rate can be achieved—this, of course, at a correspondingly high expenditure of power.

It has been found that cores can be satisfactorily obtained from hard strata, but the same success has not attended efforts to secure perfect cores in natural condition from softer strata. It will readily be recognised that these softer strata cores are the more important in oil-prospecting work.

The most important development in the refineries of the same company has been in the direction of the reconstruction of their principal refinery at Syriam, near Rangoon. It had been decided several years ago that this scheme should be carried out when conditions were favourable. Combined with this reconstruction was the concentration into the main refinery, so far as the major operations were concerned, of two smaller subsidiary units. It was essential to maintain full throughput in these refineries during the transition period, and this fact governed, to some extent, the arrangement of the reconstructed and concentrated refinery and, at the same time, rendered the processes of reconstruction and concentration much more gradual than the erection of new plant upon an unoccupied site.

Two new benches of stills, each capable of dealing with 300,000 gallons in twenty-four hours, are in service, a third of similar capacity is nearing completion, while a fourth will be dealt with when all three are in full operation. These benches are fitted with complete pre-heating arrangements, and with the atmospheric condensing system, designed and patented by Mr. Allan, the works manager of the company. The products from these benches range from aviation spirit to a heavy residuum which will serve as fuel for the steam boilers attached to the distillation benches and for fuelling stills. The results so far have been satisfactory both in quality and quantity of products and as regards fuel consumption.

In the refrigeration section of the plant a novel feature has been introduced in the form of a vertical cylindrical cooler, designed and patented by Mr. Moore, the superintending engineer of the refinery. This cooler is arranged to expose a large surface—in proportion to the space occupied—of oil to the action of the cooling medium. Its operation has been entirely successful, and it would appear that it has overcome the mechanical faults inherent in the design of coolers of older date. The Moore Cooler has proved itself a distinct advance upon any other type in general service.

The Filter Presses are so far as possible of steel, of 500 plates in each press, and are operated at high pressure. So far only a section

of the outfit is completed, but the presses now at work have proved convenient in operation and satisfactory as regards the product delivered.

The Wax Refining Section is not yet in service, but when completed will be equipped with a new type of sweating stove, designed conjointly by the gentlemen named above and known as the "Alanmor Sweating Stove." Here, again, the object aimed at is the most intimate and sectionalised contact between the paraffin wax and the heating, or, alternatively, the cooling medium. Upon experimental scale, and on a series of units of full working scale, the stove has been carefully tested and has proved itself an advance upon former practice.

It has recently been decided to adopt the principle of high vacuum distillation in the treatment of lubricating oil base for the production of high-grade lubricants, and orders have been placed for the construction of two complete units of plant to operate upon this system.

The extended use of Bauxite as a filtering medium is engaging the attention of the company's technical advisers, recent work in this connection having demonstrated still more clearly the advantages of this method of decolourising and in other directions improving the qualities of various products.

The electrical equipment of the refinery is in course of centralisation by the erection of a main power station to take the place of a number of isolated units which had been installed in course of the development of the refinery over a period of twenty-seven years.

In other directions in connection with Central Offices, Central Stores, Roadways, Lighting, etc., the refinery at Syriam is undergoing a very complete renewal and rearrangement.

Oil Separators.

By H. Barringer, M.Inst.C.E., M.I.Mech.E., M.I.N.A., M.Inst.Mar.Eng.

Owing to the recent action of Harbour Boards and Conservators of Narrow Waters in reference to the discharge of oil-contaminated water from ballast tanks, bilges, and bunker drainings, it has become desirable to establish some form of Oil Separator in order to allow vessels to discharge ballast, etc., without having to proceed to sea to carry out this operation beyond a certain limit. Even when polluted water is discharged outside the limit, the oil is eventually deposited on the shore. Several forms of apparatus

have been devised to deal with this matter, the principles on which these operate being as follows :—

(1) Consists of a barge which can be brought alongside a vessel and in which the oil is separated from the contaminated water.

The barge is divided into compartments by transverse bulkheads. The polluted water is discharged through a downcast tube to the bottom of the first compartment and rises through a series of cones which separate the major proportion of the oil. The water then passes through the other compartment, which is fitted with weirs and baffles acting as cascade filters, the effluent water being finally discharged in a purified condition. The oil is retained in a storage compartment, where it can be heated, if necessary, to remove any water still retained with the oil. In some cases the barge is divided longitudinally in the receiving chamber, there being two receiving cones side by side, with central and wing compartments arranged the whole length of the barge.

A pump is fitted in the after part to deal with the water and oil as required, and the size of a vessel to deal with 200 tons of contaminated water per hour is about 126 ft. in length, with a beam of 16 ft. 6 ins., and a moulded depth of 7 ft. 9 ins.

(2) The water to be purified is discharged into a circular chamber, which may be either placed on board ship or situated on shore. On entering the chamber the poluted water first passes into a section provided with a weir placed near the top. From this chamber it passes through a tube, the lower end of which is fitted with a cup to reverse the downward flow and project the stream in an upward direction into a large cone extending nearly from the bottom to within about one-third of the height of the chamber from the top. The tube passes through the cone, where the main separation takes place, and the oil passes upwards around heating coils to be discharged from a pipe fixed in the upper portion of the chamber. The water, which still contains a certain amount of oil, passes downward under the mouth of the large cone and over a weir into a secondary cone, taking an upward path between the primary and secondary cones. After flowing over another weir it passes through a filtering medium and is discharged in a purified condition. The dimensions of the apparatus to deal with 200 tons per hour are about 13 ft. 6 ins. diameter by 10 ft. 6 ins. in height.

(3) Consists of a U-shaped tube, 20 to 30 ft. in length, which can be placed vertically in a hold, tank, cofferdam, or bunker. The polluted water is introduced at the top of one of the arms of the U tube, and in descending passes through baffles. At the bottom it turns and rises through a smaller tube into an inspection tank, from which the clean water is drawn off. The separated oil rises to

the top of the inlet arm, which is divided by a baffle, and passing round a heating coil is drawn off at the surface.

(4) Consists of a rectangular chamber of considerable length with a sloping top. The oil and water mixture is introduced at the bottom at one end and passes under wash plates hung from the top and over baffles and weirs, the oil rising to the surface, where it can be drawn off, the purified water being discharged at the other end of the chamber.

It will be seen that the separation of oil from water is in all cases dependent on the difference in specific gravity assisted by weirs, baffles, cones, and the application of heat.

Petroleum Geology.

By J. N. Montgomerie.

The year under review can be regarded with a certain degree of satisfaction as one of steady progress towards a knowledge of the processes and principles involved in the origin and accumulation of petroleum.

Whilst widely differing hypotheses and conceptions continue, and general agreement is yet far off, the road leading to the establishment of sound theories and, perhaps, even laws on these important problems, is being paved by many investigators.

Tectonics and stratigraphy have received due attention, and some refreshingly new ideas have been propounded on the former. Work on stratigraphy is necessarily less spectacular, but the painstaking efforts of stratigraphers and palæontologists have resulted in the better establishment of the age of certain valued reference horizons in various parts of the world and the widening of correlated areas.

Many new areas and fields were mapped and described in detail, and countries of which but little was known geologically reconnoitred.

Besides all this published information, there yet remains the far greater and wider volume of work accomplished by geologists on behalf of the various oil companies, both large and small, the painstaking and accurate large scale mapping, the correlation of groups and construction of stratigraphic columns, the interpretation of tectonic enigmas, and the collection of data relative to the origin and accumulation of petroleum, much of which necessarily remains se ret until its immediate commercial purpose is fulfilled, but, nevertheless, represents a considerable addition to the more

widely diffused information, since its cumulative effect is felt in the broadened outlook of those engaged in such work.

Brief outlines of the points raised by the more interesting items or papers for the year follow under the headings :—Origin, Migration and Accumulation, Tectonics, Stratigraphy, Field Methods, etc.

Origin of Petroleum.

On the geological side the tendency of the work accomplished has been in the direction of confirming and consolidating the Vegetational Theory. In the previous year Von Höfer, in a fourth edition of his "Das Erdöl und Seine Verwändten," re-affirmed his conviction of a predominantly animal organic origin, and thus remains the outstanding figure of the "Animalists."

Support for the Vegetational Theory has been provided by two independent items of evidence in the United States, described under "Suggestive Evidence on the Origin of Petroleum and Oil Shale" (J. Claude Jones, Bull. Am. Ass. Pet. Geologists, Vol. VII., No. 1, pp. 67-72) and "Some Mother Plants of Petroleum in the Devonian Black Shales" (David White and T. Stadnichenko, Econ. Geol., Vol. XVIII., No. 3, pp. 238-252). In the former note the evidence is provided by wells drilled through the sediments of a formerly extensive lake (Lake Lahontan), now represented by several relic lakes in North-western Nevada, and silts of the present lakes. Present evidence indicates a beginning as a fresh-water lake about 2,400 years ago, and, in the absence of an outlet, an accumulation of salts until the present Pyramid Lake, one of the largest remnants, has a salinity of 3,500 parts per million.

Silts laid down under fresh-water conditions contain comparatively fresh algal fragments. On the other hand, algæ, etc., in silts at present depositing or laid down under salt-water conditions are partly decomposed and oleaginous material, comparable with petroleum, has been found associated with them. The evidence is considered as suggesting a tentative hypothesis that oil shales originate as fresh-water muds, containing a large percentage of algæ, spores, and other non-woody vegetal material, which has been partially decomposed by bacterial action, but not sufficiently to raise appreciably the relative proportion of fats through removal of other plant substances.

The origin of petroleum is in muds, sands, and calcareous muds, deposited in saline waters and containing a considerable percentage of organic matter, largely algal in origin, but may in special instances consist of other plants and animal remains, which have been so thoroughly decomposed through bacterial action that the fats form a relatively high percentage of the organic material remaining.

The chief difference in the origin of oil shales and the sediments

giving rise to petroleum lies in the degree of bacterial decomposition of organic matter, which, in turn, depends on the salinity of the water in which the decay takes place.

The above deductions have since been challenged as untenable by W. G. Weeks, on the grounds that all oil shales do not contain partly decomposed vegetal material, certain oil shales are definitely marine, and the oil in these is either original or migrated, either being fatal to the hypothesis, and that no account is taken of derived oil shales containing adsorbed oil. This discussion, however, in no way invalidates the evidence, or the additional light it throws on the rôle of salt water in oil formation.

The second item quoted deals with two types of fossil plants occurring in black shales, regarded as of Genesee age, in North-eastern Kentucky. Both are marked by a strengthening of the outer wall-cells by a reddish-brown, waxy-resinous material, and the paving of the outer surface by a yellow translucent waxy secretion. The plants are specially resistant to decay and at the present moment are high in hydrogen and low in oxygen, and particularly adapted to the generation of hydrogen-rich hydrocarbons. They are associated with hard, wax-like spore exines, and are important sources of artificial oil obtained by distillation of the containing shale. The authors regard their office in the generation of petroleum, in the course of elapsed geologic time, as a logical conclusion.

A notable publication, indicating the interest in this aspect of petroleum geology, was provided in "The Genesis of Petroleum," by Percy E. Spielman, in which the author expresses a conclusion that oil is formed by the action of ærobic bacteria on both animal and vegetable material in the sediments of saline or brackish seas or lagoons.

The ultimate composition of any particular petroleum will be affected by filtering and catalysis during migration, as well as by the nature of the original organic material and its geologic age.

Mr. E. H. Cunningham-Craig, in a paper entitled "Recent Researches Bearing upon the Origin of Petroleum" (*Ibid.*, Vol. IX., No. 39, pp. 344-167), cites further cases of a petroliferous horizon passing laterally into a lignitic or carbonaceous phase, on the lines of his well-known examples, from such widely separated countries as Venezuela, Burma, Hungary and Rumania.

On the basis of the successful hydrogenation of certain coals by the Bergin process, Mr. Cunningham-Craig suggests that, in an autoclave, vegetable matter not up to the coal stage, in which the carbon-hydrogen ratio has not risen too far, and is therefore sufficiently rich in hydrogen, under sufficient pressure, we would expect petroleum to form. In the later discussion, however, Dr. Dunstan drew attention to the fact that the products of Berginisation of coal were not like petroleum.

Mr. Craig also drew conclusions from the relation of coal, torbanite, oil shale and free oil in support of the vegetable origin of free petroleum.

Other summaries and ideas advanced during the year were in the greater part modifications or re-iterations of earlier ones.

Migration and Accumulation of Petroleum.

1923 was marked by continued activity in experiment and field-comparison among American geologists to solve the principal factors of these related problems.

An outstanding hypothesis, limited though it is in application, was published by R. Van A. Mills (Bull. Am. Ass. Petr. Geologists, Vol. VII., No. 1). Briefly, this hypothesis, based on impressive laboratory experiments and backed by selected field evidence, states that under favourable conditions faulting has yielded open fissures and caused release of pressure. Immediately upon the release of pressure, gas absorbed by the oil and water expands and propels them towards the point of release, the oil more effectively than the water. Such migration has been upward, but fissuring has also facilitated the lateral migration of oil and gas through porous beds towards these points of escape, which corresponds to the lateral migration through sands towards producing wells. This has been a comparatively rapid process; not the long drawn out process that is generally pictured. In testing a faulted structure, deep tests are advocated, as shallow sands will have suffered more advanced drainage.

The Hydraulic Theory of Oil Migration, as stated by Rich in 1921, was further discussed by the same writer, and further evidence in favour supplied from the San Juan Basin, the Kevin-Sunburst field, and the Mexia field (Bull. Am. Ass. Petr. Geologists, Vol. VII., No. 3, pp. 213-225). This writer regards Mills's hypothesis as a significant contribution to our knowledge of the possible causes for oil migration and accumulation, and accepts it as revealing a new and effective cause for hydraulic currents and introducing a new factor in entraining and propelling the oil.

Faulting at Mexia is considered a primary factor in the accumulation of oil at that field by Wallace E. Pratt and F. H. Lahee (Bull. Am. Ass. Petr. Geologists, Vol. VII., No. 3, pp. 226-236), and they claim that a much wider application of the principles involved is justified.

That the age of an oil pool is defined by the age of the structure—not the bed—in which it is found is advanced by F. F. Hintze in a paper entitled "Oil Accumulation in Relation to Periods of Folding" (Bull. Am. Ass. Petr. Geologists, Vol. VII., No. 1, pp. 58-66).

Oil accumulates soon after suitable structure is formed, and beds folded while young and unconsolidated favour accumulation, whilst old beds affected by new, or late structures, are of doubtful value form his most useful conclusions.

Whilst the general trend of opinion is away from accepting buoyancy as the primary factor in oil migration, capillarity appears to lose none of its importance, especially in explaining the movement from shale to sand—in fact, it still holds sway as the initial factor, though its importance in the later stages of accumulation may become subordinate to water-flush and gas-propulsion.

In this connection Charles W. Cook has obtained an interchange of oil and water in a suitable apparatus (Econ. Geol., Vol. XVIII., No. 2, pp. 167-172), with a capillary tube connecting two chambers containing originally coarse sand and water on the one hand, and fine sand with oil on the other. The water moved along the sides of the tube in one direction, whilst the oil moved as a solid column through the middle of the tube in the opposite direction. The experiment indicates a necessity for some modification of assumptions usually made the basis for the so-called capillary theory.

Tectonics.

Among papers of general geological interest for the year, that on "Similar, Parallel, and Neutral-surface types of Folding" (E. L. Ickes, Econ. Geol., Vol. XVIII., No. 6, pp. 575-594) is of particular interest to the petroleum geologist. Similar folding, in which the surfaces of the successive beds match, is rarely taken into account, yet its incidence in folded shales appears to be by no means rare and may affect the hade of the axis of an assymetrical fold considerably, whilst its influence on drilling depths is not negligible.

Carpathian structures continue to attract attention, and some new and novel interpretations were advanced during the year.

Dr. Maxmilian Kraus (Oil Deposits and the Tectonics of Vertical Pressure, *Ibid.*, Vol. IX., No. 38) concludes that the peculiar structures of the Carpathian region result from differential vertical pressures, sufficient to overcome internal friction in rock materials which are naturally or potentially plastic. Material migrates from areas under high pressure to zones of less pressure, and there causes an upward movement with, in extreme cases, the core of migrating material piercing the younger strata and developing a thrust plane conforming to a logarithmic spiral, with its concave side towards the area of higher pressure; in other words, diapyric anticlines.

This may result in an open structure which is favourable to the accumulation of oil. In the region cited Dr. Kraus considers the oil indigenous to the younger strata.

Dr. Voitesti in the same publication also deals with the Carpathian structures and expresses views widely divergent from the above. He regards the close connection between the productive deposits, and the situation of salt domes along zones of dislocation, as a result of the same tectonic movement and the upward migration of both salt and oil, along the planes of dislocation, from depth. The distribution of the petroleum follows the disposition of the salt and the ability of the faults to penetrate the higher strata.

The petroleum is ascribed to distillation of the older sedimentary formations, rich in organic material, under incipient regional metamorphism. The connection between the salt and the petroleum is only tectonical and not genetical. This theory dismisses that of the salifère stage origin.

Stratigraphy and Palæontology.

Items of general interest and broad application are confined to palæontology. Quoting from his own experience in America of the relative dependableness of different kinds of fossils, G. Wythe Cook briefly indicates the most useful phyla for zoning (Bull. Am. Ass. Petr. Geologists, Vol. VII., No. 2, pp. 183-186). The larger genera of the Foraminifera, Corals, Echinoids, and Molluscs, particularly Pelecypods and Gasteropods are favoured as providing the best types. Plants are often questionable and lead to faulty correlations.

Thomas Wayland Vaughan has, by means of a comparative census and tables, investigated the relative value of species of the smaller Foraminifera for the recognition of stratigraphic zones (Bull. Am. Ass. Petr. Geologists, Vol. VII., No. 5, pp. 517-531). Molluscs, Corals, and Bryozoa provide the necessary comparatives, and the conclusion that the smaller Foraminifera possess the least value of any of the organisms considered is reached. Fifty per cent. of the species of smaller Foraminifera in the lower Oligocene examined would not distinguish between Oligocene and Recent.

Field Methods.

The application of the torsion balance to determination of underground densities, and by this means the detection and defining of structures suitable for accumulations of petroleum, made steady headway, and its still wider application seems certain.

A yet unproved, but nevertheless suggestive, method of defining areas underlain by petroliferous materials has been put forward by a Russian geologist, L. N. Bogojavlensky, in the Petroleum and Oil Shale Industry Magazine, No. 2. As compared with

water, oils are stated to possess a greatly superior power of absorbing radio-active emanations, and the originator concludes that "every oil deposit, even in sedimentary rocks, must have a greater radio-activity as compared with that of the enclosing rocks." It is claimed that it is possible to construct curves (isorads) connecting the points of equal intensity of the earth's radio activity, previously determined, thus delineating the radio active body or area.

In connection with field methods it is of interest to note that tests recently carried out in Germany, on the lines of earlier ones in Australia and America, of the use of the divining rod, or wiggle-stick, under geological supervision, resulted in a thorough discomfiture and exposure of the "artists."

General.

Relative to the indicating of new areas of potentially petroliferous rocks, sericitisation and dolomitization, which have been suggested as providing an index, in the absence of coal, on the lines of the "fixed carbon ratio," to the petroleum possibilities of any given sedimentary rock, are stated by Lahee to be valueless.

Sericite does not appear until metamorphism has reached a stage beyond the carbon 65 per cent., and dolomite may not only be original but its secondary origins are too diverse to provide a criterion as to the degree of dynamic metamorphism.

The Rumanian Petroleum Industry in 1923.*

By CRISTIAN LEU.

1. *General Outlook.*—The Rumanian Petroleum Industry, suddenly arrested by the war in its path of rising prosperity, has experienced such considerable destruction that the problem presented in 1918 has been blended from the beginning with that of constructive work necessary almost in its entirety.

The conditions under which this difficult action had to be undertaken were greatly influenced by the general economical state of the country, which was itself in a very precarious state in 1918. These conditions have determined all the Rumanian Governments since the war to adopt an interventionist policy of a restrictive character in regard to the petroleum industry. The exceptionally favourable conditions offered to petroleum products

* Translated from the French by Mr. J. E. Marshall Hall.

immediately after the war, in free traffic, should have permitted the realisation of considerable profits and consequently a rapid reconstitution of damaged fields as well as of technical tool outfits. But the rapid development of this industry in a medium of misery would have brought about an excessive costliness of life in an automatic manner, as well as the consequences so unfavourable in the social economy into which all Governments have been thrown in countries injured by the war. This is why the idea has been conceived of imposing on the petroleum industry, the only thing favoured by events since the war, a sacrifice compelled by the general economy of the country.

In this manner it has been sought to balance in some way the consequences of the war, favourable to the one thing but a source of difficulties for the rest. This forced sacrifice has on the one hand a certain restrictive effect upon the outlook of a rapid reconstitution of the petroleum industry, without, however, having hindered the evidently improving course of its progress; but, on the other hand, this very sacrifice has acted as a counterpoise in the same degree in reviving the regenerative tendencies of general economy. Thus the interventionist policy, seen through the glass of the superior interests of the State, appears justified in its chief basis. This policy has shown itself practically by a series of restrictive enactments of a temporary nature, limiting the quantities designed for export according to a normal, capable of insuring first the national consumption as maximum prices—that is to say, fixed and below the price of free commerce.

Inspired by the same principles, the existing Government has realised in 1923 the most important event ever registered in the annals of the Rumanian petroleum industry—viz., the inclusion in the Constitution of the principle of the nationalisation of the subsoil, respecting all acquired rights. This legislative work, as well as all the restrictive dispositions of a temporary nature above mentioned, have provoked a keen criticism on the part of the petroleum circles directly interested, which have clearly affirmed, and in an increasingly energetic manner, the necessity for a condition of absolute liberty in the valuation of petroleum products. Consequently, the successes recorded as well as the aspects characteristic of this struggle, have shown on the one hand that the road towards free trading can only be acquired by successive steps, but on the other hand that this end does not appear to be too far from being realised. The enervating atmosphere which characterises this state of affairs in latter years in the social-economic substratum of the petroleum activity has taken an increasing course more and more accelerated as the value of the money of the country depreciated, and parallel also to the drop of price in free commerce. which has culminated towards the close of the year

1923. This epoch itself also coincides with the prelude of a free *regime* by the accepting of the "Mexican Gulf Fob" as basis for interior traffic. Nevertheless, the aspect in some degree negative of this enervating atmosphere has been largely compensated by a positive activity developed so vigorously in 1923 that this year, whilst showing a normal progress, is at the same time marked by the objective criterion of statistical data, as a stage of feverish preparation, capable of equalising after a short delay the forced sacrifice imposed by the interventionist policy of the State.

2. *Capital. Companies.*—The nominal capital of Rumanian enterprises has shown an important increase in the course of the year 1923, thus :—

(*a*) On January 1, 1923, there existed 150 legally constituted companies, with a total nominal capital of £137,428,294.

(*b*) During this same year seventeen companies have been formed in Rumania, with a total nominal capital of £5,357,143.

(*c*) In the same interval four companies have been formed in England with a nominal capital of £2,030,000. These four companies are :—

	£
Minerva (Roumania) Oil Co., Ltd...	500,000
Sospiro Oilfields, Ltd.	1,365,000
Arinis (Roumania) Oilfields, Ltd.	150,000
Pacura Oil Co., Ltd...	15,000
	£2,030,000

(The formation in London of the Incorporated Anglo-Rumanian Industries, Ltd., with a nominal capital of £200,000, has been announced, but up to December 31, 1923, the company has registered no activity in the country.)

(*d*) Thirty-two companies, representing on January 1, 1923, a total nominal capital of £78,291,667, have increased their capital by £106,142,857—*i.e.*, by 135 per cent., of which £66,666,667 is effective. These thirty-two companies, therefore, represented on December 31, 1923, a total nominal capital of £184,434,524.

(*e*) Consequently, on December 31, 1923, 171 companies were in existence, with an effective capital of £203,138,532, and a total nominal capital of £250,958,294.

Thus, during 1923 an increase in nominal capital of £113,530,000, or 96 per cent., has been realised.

It must be noted, however, that the above figures have been calculated at the pre-war par value of the lei—*i.e.*, 25·20 lei to the pound sterling. Calculated in actual money, the capital represents about 20 milliards of lei.

The foreign capital most strongly represented in the Rumanian petroleum industry is English. On December 31, 1923, 27 English companies existed, with a total nominal capital of £13,947,334. This sum in actual money is equivalent to about 11 milliards of lei, or over 50 per cent. of the total capital employed in the industry in Rumania.

3. *Activity in the Fields.*—During 1923 drilling activity in Rumania has exceeded all previous records :—

Year.	Metres drilled.
1915	95,000
1920	18,500
1921	47,200
1922	87,300
1923	121,000

This remarkable effort has necessitated a total expenditure of about 1,600,000,000 lei ; that is to say, almost the effective total of the increased capital of the 32 companies during the year.

The most intense drilling activity has been by the English company, " Phœnix Oil and Transport Co., Ltd.," which takes first place with 20,000 metres drilled.

The following table shows the position with regard to hand-dug and drilled wells :—

	Abandoned.	Working.	Productive.
Hand-dug Wells.			
Jan. 1st, 1923	368 ..	55 ..	271
Dec. 31st, 1923	419 ..	137 ..	297
	51	82	26
Drilled Wells.			
Jan. 1st, 1923	333 ..	480 ..	795
Dec. 31st, 1923	416 ..	554 ..	899
	83 ..	74 ..	104

During the year 159 hand-dug and 261 drilled wells have been working, a record in the Rumanian petroleum industry ; and this activity proves the confidence in the richness of the Rumanian petroliferous sub-soil. The majority of the wells drilled have been in the fields already exploited, and this is explained by the fact that many concession contracts are nearing expiration. In the course of the year the exploiting of petroleum by shafts and galleries in Rumania has been commenced, the experiment being executed by M. Munteanu on his Doftana concession, Bacau.

During 1923 the richness of the northern flank of the Moreni region has been confirmed, thus opening up a new important

field—Moreni-Stavropoleos-Nord-Pleasa, the westward extension of which is also proved by drilling northward of the region of Gura-Ocnitzei. The northern limit of this field presents many possibilities of development. Exploration work continues at Pacuretzi, Baicoi, Tzintea, Runcu, Gropi, Blodeshti, Floresti Draganeasa, Podenii-Noui, Ceptura, Tega, Rasvad and Govora, and has given results of good augury for the near future.

At Ariceshti the work of the "Steaua Romana" and "Romana Americana" companies has confirmed the existence of important deposits of natural gas, which are being exploited, their richness being remarkable.

4. *Production of Crude Petroleum.*—The production of petroleum in 1923 shows an increase compared with all preceding years since the war, as shown in the following tables :—

	1922. Metric tons.	1923. Metric tons.
January	102,395	128,146
February	100,883	116,624
March	118,203	138,150
April	110,724	129,077
May	121,233	124,633
June	113,688	124,474
July	115,826	126,503
August	114,927	127,073
September	110,285	120,067
October	114,954	120,664
November	112,775	123,367
December	129,872	131,026
Total	1,365,765	1,509,804

Year.	Quantity. Metric tons.
1919	920,437
1920	1,037,048
1921	1,163,765
1922	1,365,765
1923	1,509,804

It will be seen that the increase of 144,039 metric tons in the year 1923, as compared with 1922, or 10·5 per cent., is less marked than in former years. The percentage differences in production in these years show in every case an ascending scale of almost constant uniformity. Compared with the maximum annual production realised in Rumania, 1,885,225 metric tons in 1913, the yearly outputs since the war represent in percentages of this figure :—

1919	48·8 per cent.		1922	72·6 per cent.	
1920	55·0 „		1923	80·1 „	
1921	61·7 „				

That is to say, an harmonic ascending progress, which allows us to foresee that the 1913 figure will be normally passed in 1926.

Certain indications, however, allow us to anticipate that the maximum production will be passed in 1925.

The following tables show the production in 1922 and 1923 by fields and by districts :—

PRODUCTION BY FIELDS.

Field.	1922. Quantity. Metric tons.	1922. Percentage of total.	1923. Quantity. Metric tons.	1923. Percentage of total.
Moreni	609,877	44·7	665,490	44·1
Ochiuri	139,260	10·2	202,594	13·4
Bushtenari ..	197,462	14·5	197,094	13·1
Gura Ocnitzei ..	38,838	2·8	104,038	6·9
Arbanashi.. ..	91,436	6·5	88,860	5·9
Baicoi	126,331	9·3	78,981	5·2
Campina	66,354	4·9	65,357	4·3
Tzintea	46,029	3·4	52,865	3·5
Other Fields ..	50,178	3·7	54,525	3·6
Total.. ..	1,365,765	100·0	1,509,804	100·0

PRODUCTION BY DISTRICTS.

District.	1922. Quantity. Metric tons.	1922. Percentage of total.	1923. Quantity. Metric tons.	1923. Percentage of total.
Prahova	1,055,581	76·5	1,070,380	70·9
Dambovitza ..	179,156	13·1	307,648	20·4
Buzau	92,298	6·9	89,758	5·9
Bacau	38,730	3·5	41,973	2·8
Maramuresh ..	—	—	45	—
Total.. ..	1,365,765	100·0	1,509,804	100·0

From the above tables will be seen the importance of the new fields of Dambovitza, Gura Ocnitzei, and Ochiuri, which show a tendency to surpass in the future the dominant importance of the Prahova district, of which the output is clearly declining. It may be remarked that the Ochiuri fields belong almost entirely to the English company, "Phœnix Oil and Transport Co., Ltd."

Thus, the productive region shows a global displacement towards the west, starting with Moreni-Stavropoleos.

Practically the whole of the production in 1923 has been furnished by the following companies :—

Company.	Year of Formation.	Capital. Nominal. £	Capital. Effective. £	Production in 1923. Metric tons.	Production in 1923. Percentage
1. Astra-Romana	1916	17,857,143	17,857,143	414,122	27·5
2. Steaua - Romana	1896	18,452,381	18,452,381	222,676	14·7
3. Romano - Americana.	1904	19,841,270	19,841,270	163,630	10·8
4. Credit Minier	1919	19,950,397	8,556,548	158,050	10·5
5. Internationala	1899	314,166	244,388	104,767	6·9
6. Colombia	1905	5,476,190	5,476,190	87,866	5·8
7. Concordia	1907	9,722,222	9,722,222	61,751	4·1
8. I.R.D.P.	1920	23,809,524	10,267,857	57,453	3·8
9. Unirea	1921	3,968,254	3,968,254	46,061	3·1
10. Orion	1910	3,376,984	2,067,460	44,221	2·8
Total		£122,768,531	£96,453,713	1,360,597	100·0
Percentage of total		45·60	47·48	90·1	—

Thus it will be seen that out of a total of 171, ten companies, representing practically half (45·6 per cent.) the total nominal capital and nearly half (47·48 per cent.) of the called-up capital, have afforded almost the whole (90·1 per cent.) of the production for the year 1923.

These are the companies which have shown the most important increase in capital during the year.

The following tables show the profits which these companies have realised during the course of the last performance :—

Company.	Gross Profit. £	Percentage of Effective Capital.	Dividends. Per cent.
1. Astra-Romana	30,818,214	173·0	165·0
2. Steaua-Romana	12,660,794	68·6	50·0
3. Romano-Americana	8,005,000	40·4	22·5
4. Credit Minier	2,535,675	29·6	30·0
5. Internationala	2,452,619	31·4	—
6. Colombia	3,793,254	69·3	—
7. Concordia	8,288,254	85·3	75·0
8. I.R.D.P.	1,498,373	14·6	12·0
9. Unirea	4,791,786	120·7	—
10. Orion	2,185,437	105·7	—
Total	£77,029,406	84·2 per cent. of the total profits of all companies.	—

The gross profit realised represents 62·7 per cent. of the nominal capital and 84·7 per cent. of the called-up capital of these ten companies. The rentability of the companies, which have been showing full exploitation in the year 1923, has been remarkable. The increase of capital realised has been covered by the dividends, but at the same time they have been compelled to issue new shares

owing to the lack of ready money. This proves on the one hand that the rentability of last year has not been affected in a very unfavourable degree by the forced sacrifice mentioned above, and on the other hand that the profits which have been realised have immediately found a positive application in drilling activity, which is necessary in order to maintain the advance gained by these important companies.

It may therefore be predicted that as the remaining companies enter upon the productive phase, prepared in a vigorous manner during the last year, the production of crude petroleum will show an increase of accelerated order, and will doubtless bring Rumania, after a short delay, to its pre-war position among the petroleum-producing countries.

Before the war the production of petroleum in Rumania stood fourth, after the United States, Russia and Mexico, but the war caused a retrograde movement.

5. *Activity of the Refineries.*—The following quantities of crude petroleum have been sent to the refineries during the last two years :—

	Metric tons.
1922	1,212,823,000
1923	1,327,205,000

That is to say, a difference of 114,382 metric tons in favour of 1923 (+ 10 per cent.).

In the same period the following quantities of products have been obtained :—

Product.	Quantity in metric tons. 1922.	1923.	Percentage increase or decrease.
Benzine	285,097	300,847	.. + 5·5
Lamp oil	214,473	213,206	.. − 0·6
Lubricants and gas oil ..	112,968	126,103	.. + 1·6
Residue	573,468	667,535	.. +16·4
Total	1,186,006	1,307,691	.. +10·2

The quantity of petroleum treated in the refineries in 1923 represents a percentage of 88·6 of the total year's production. In 1921, 92·5 per cent. was treated, and in 1922 90 per cent. It will be seen that the quantities have decreased systematically, which is a clear index to the crisis in combustible liquids, shown besides in a more and more accentuated manner.

6. *Internal Consumption and Exports.*—The consumption of petroleum products in Rumania shows the following fluctuations in later years :—

	Quantity in metric tons.					
	1914.	1919.	1920.	1921.	1922.	1923.
Benzine	31,672	41,267	25,817	51,469	74,956	86,588
Lamp oil	51,710	51,470	64,422	70,660	88,647	97,299
Lubricants and gas oil	40,816	39,950	47,781	76,827	124,572	116,582
Paraffin wax	1,416	949	621	1,087	1,582	1,609
Residue	524,254	263,857	269,827	332,143	394,686	462,854
Total	649,868	397,493	408,468	532,186	684,443	764,932

Taking the population of Rumania as 7·5 millions in 1914, and 16 millions for 1919 to 1923, the consumption per person has been :—

	Kgr.		Kgr.
1914	84·7	1921	33·2
1919	24·8	1922	42·8
1920	25·5	1923	47·8

These figures show the crisis in the internal consumption of combustible liquids. We are still very far from attaining the normal mean of the year 1914. The figure should be still greater, as industrial activity since the war, with the addition of the new provinces formerly belonging to Austria-Hungary, is much greater than that which existed prior to the war.

It is seen that this crisis is diminishing, but slowly, and for some years exports will be influenced by this state of affairs. The normal state in internal consumption, calculated per head of population, will probably be attained when double the maximum production of 1913 is reached.

Exports show a diminution in 1923, as compared with 1922 :—

	Metric tons.
Total exports, 1922	430,226
Total exports, 1923	384,142

This is also a reflection upon the persistent crisis of combustible liquids, at the same time noting better transport conditions and the result of a more accentuated demand in the country, a crisis that it has been sought to reduce to its minimum.

The following table shows the distribution of petroleum during the last two years :—

	1922.		1923.	
	Quantity. Metric tons.	Percentage of total.	Quantity. Metric tons.	Percentage of total.
Internal consumption ..	684,542	50·0 ..	764,932	50·7
Exports	430,226	31·5 ..	384,142	25·4
Fuel in the refineries ..	145,567	10·6 ..	135,941	9·0
Stocks	108,594	7·9 ..	224,789	14·9

Proportional to the total production, the internal consumption exhibits a constant percentage, 50 to 50·7. Exports have been

affected, among other things, by the hope of more favourable conjectures in free commerce, in view of the decrease of prices noted in a systematic manner at the end of 1923, and for this reason the stocks show a parallel growth.

The bureau O.K.Z., formed to control and regulate transports by rail, has furnished interesting data rich in valuable conclusions.

The transport of oil by rail during the four quarters of the year is given below :—

1923.	Total. Cisterne-wagons of 10 metric tons.
January to March	18,345
April to June	21,562
July to September	20,748
October to December	19,160
Total	79,815

The diminution of transport in the last quarters, and more especially in the three months, October to December, is very characteristic. Whilst showing signs in the crisis in the means of transport, it reflects also the struggle towards the end of the year against State intervention.

All the aspects under which the State policy will show itself in regard to petroleum during 1924 are not yet known. To judge by indications which have hitherto been afforded, we can conclude that the year presents itself under much more favourable auspices, and compared with activity on the fields this year will certainly mark a more accentuated progress for the petroleum industry than that experienced in the later years since the war.

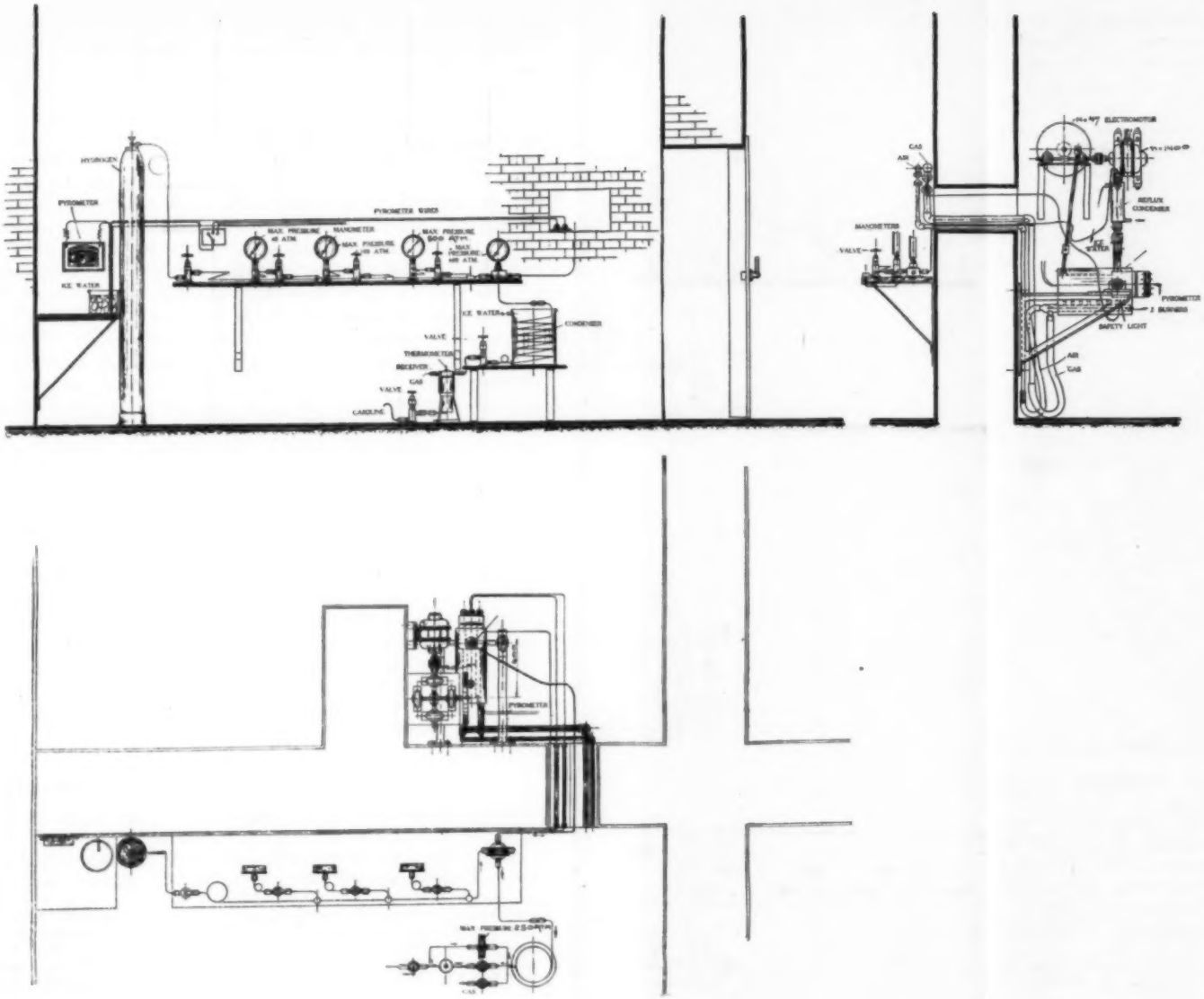
Hydrogenation by the Bergius Method.

By H. I. Waterman and J. N. J. Perquin.

By a series of investigations which were carried out in the laboratory of Chemical Technology of the Delft Technical University we have studied this interesting method,[1] which has attracted attention in countries possessing much coal and but little petroleum.

Although the research taken up by us concerning the scientific and technical significance of Bergius' hydrogenation process will

[1] We wish to express our thanks to Mr. E. J. Wing Easton and Mr. J. A. Beukers, chemical engineers, for their assistance during the course of this research.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MAX. PRESSURE 400 ATM.
ICE WATER
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GAS
VALVE
GASOLINE
GAS
AIR
MANOMETER
VALVE
REFLUX CONDENSER
ICE WATER
PYROMETER
BURNERS
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XXVII,
[2] F. J.

occupy many more years of study, while a thorough experimental ability and a highly specialised knowledge of the different kinds of apparatus are necessary, we give here a summary of the most important results.[2] The comparison of the unsaturation of the distillates obtained is very difficult. The degree of unsaturation can be most easily determined by the iodine or bromine absorption value, but this method gives substitution and addition at the same time. The determination of the aniline point, which, too, is very easy, gives other difficulties. The aniline point depends on the nature of distillate, while the lowering of the aniline point is almost proportional to the percentage of aromatic hydrocarbons. The same percentages of benzene, naphthalene and anthracene do not give the same lowering of the aniline point.

In our research we employed chiefly the bromine-value method of McIlhiney. The substituted bromine is subtracted from the total amount of the absorbed bromine. The remaining quantity gives a measure of the degree of unsaturation, and is expressed in percentage of weight of the distillate. However, when under the action of bromine there is formation of "carbon," the method of McIlhiney, instead of addition and substitution, indicates adsorption by the "carbon" and dehydrogenation.[3] In such cases, therefore, this method cannot be used.

(*a*) *Hydrogenation of Mexican and Borneo asphalt, using a vertical immovable autoclave.*

In the first place, we proved that, as compared with cracking under comparable circumstances, the Berginisation of Mexican asphalt and of Borneo asphalt can give the typical pressure curves of Bergius. The influence of temperature is very important, and naturally depends on the kind of raw material experimented with, and on the apparatus used. Like Bergius, we found the specific gravity of the residue from the Engler distillation of the oil was lower by Berginisation than by the corresponding cracking experiments.

(*b*) *Hydrogenation of paraffin wax.*

Owing to the peculiar advantages which commercial paraffin offers for these experiments over other materials such as asphalt, we have chosen paraffin wax. Paraffin wax is much more easily analysed than asphalt, and this holds also for the products pre-

[2] For a more detailed description of our experiments see H. I. Waterman and J. N. J. Perquin, Recueil des Travaux chimiques des Pays-Bas **40**, 677 (1921); **41**, 192 (1922); Congrès international des combustibles liquides, Paris, Chimie et Industrie, numéro spécial Mai **1923**, p. 200 Proceedings Koninklijke Akademie van Wetenschappen Amsterdam, XXVI, 226 (1923); XXVII, 83 (1923); XXVII, 132 (1924).

[3] F. J. Nellensteyn, Chemisch Weekblad **21**, 102 (1924).

pared from paraffin when they are compared with the corresponding substances formed in the treatment of asphalt. Thus paraffin yields products that are less strongly coloured than Mexican asphalt. For these experiments we had an autoclave, which was shaken continuously, at our disposal. The paraffin wax had a sp. gr. at 15°/15°C. of 0·913, the solidifying point (Shukoff method) was 50·6°C.; the bromine value (addition) was 0·5 and could therefore be neglected. The temperature of the experiment was 435°C. Stones were put in the autoclave to promote mixing. The oils obtained by the Bergius process were coloured from yellow to red and perfectly transparent; a small quantity of "carbon" was deposited on the bottom. The oils obtained in cracking were very dark of colour and opaque. Here, too, separation of some carbon is found.

The quantity of carbon which is deposited on the bottom, when the weight of carbon which has already been deposited on the stones is added, is so small, both in the cracking and in the Bergius method, that, if the duration of the experiments is long enough, practically the paraffin wax is entirely converted into oil and gas in both processes.

The yield of gasoline does not differ much in the two processes.

There is a great difference in the nature of the residues left on the distillation of the oil obtained according to Engler. Its specific gravity is always lower in the Berginisation experiments than in the cracking experiments, which is a confirmation of corresponding experiments made by Bergius. It appears from the final pressure and also in connection with the gas analysis (percentage of hydrogen) that actually considerable quantities of hydrogen are absorbed in the Berginisation.

The bromine addition value of the oils obtained by Berginisation is lower than that of the oils from the corresponding cracking experiments.

The example given here proves convictingly that a determination of the yield of oil and gas from a solid substance does not suffice to enable us to form a correct opinion on the process of Bergius.

A comparative cracking experiment is required for this. Possible results refer only to the procedure followed, in this case to the periodic process, the temperature of the experiment, etc. The Berginisation necessarily is associated with the cracking process, which explains the great influence of temperature. If in cracking experiments hydrogen is found in large quantities, then at high pressure, "internal hydrogenation" may be possible. ("Internal" in opposition to the hydrogenation with external hydrogen as in the Bergius experiments.)

(c) *The decomposition of cottonseed oil at 450° C. compared with the hydrogenation of this oil by the method of Bergius.*

In the Berginisation of products containing carbon and hydrogen one has only to deal with two processes—the process of cracking and the process of hydrogenation. In this case, however, the matter was somewhat more complicated because here the hydrocarbons must first be formed from fats. We worked at 450° C. The high-pressure apparatus was constructed for this purpose (Fig. 1). The temperature in the metal wall of the autoclave was measured, by which it was ascertained that there was no question of any overheating of the walls during the experiments.

The change of the pressure during the Berginisation is essentially different from that in the cracking experiment. The rise of the pressure is considerably smaller in the Berginisation than in the cracking. It appears from the gas analysis that the oxygen of the cottonseed oil is driven out in both cases almost quantitatively as CO, CO_2 and H_2O.

Both by cracking and by Berginisation cottonseed oil can very efficiently be converted into hydrocarbon mixtures with high gasoline percentage.

In these experiments the behaviour of the cottonseed oil is not very different from that of a hydrocarbon mixture, as the oxygen can easily be eliminated from it. In the Berginisation of the cottonseed oil very much hydrogen is consumed; among other ways directly or indirectly in the formation of water.

In both processes formation of coke takes place (about 7 per cent. in the cracking experiments), this being considerably less in the Berginisation experiments (0·3—0·5 per cent.).

(d) *Conversion of paraffin wax by heating under pressure in the presence of hydrogen, methane and other gases.*

In the table one finds a review of the most important results.

The two experiments in which during the heating gas was blown off were the numbers 58 and 59.

In 58 the reflux cooler was not provided with cooling water, while the autoclave was kept closed until the pressure amounted to seven atmospheres.[1]

Hereafter gas was blown off continuously and the pressure kept constant at seven atmospheres.

In 59 the autoclave was filled with nitrogen up to seven atmospheres before the beginning of the experiment; the gases could therefore be blown off from the beginning of the heating. The

[1] A clogging of the tubing caused the pressure to rise to 14 atmospheres for about 10 minutes.

conditions in 58 and 59 have some resemblance to those that occu in cracking processes such as the Burton process.[1]

Though the significance of the change in pressure, after th temperature has become constant, has not been definitely settled a consideration of the pressure curves can give some understandin whether or not we have to do with analogous processes.

A difficulty with this is, however, that, *e.g.*, a relative pressur lowering may be caused by the addition of hydrogen (hydrogenatio or by polimerisation in the gaseous phase[2]).

Of all the experiments mentioned in the table only in 58 and 5 was a distillate obtained during the experiment. In 58 the dis tillate became solid at 0° C., the bromine value being very high 76·5, while the residue in the autoclave was liquid and had a bromin value of 24·6.

In 59 the bromine value of the distillate was 82·7, and of th residue 39·7. The residue contained gum-like constituents. For further research a portion of the distillate and residue of 58 and 59 were mixed in the proportion by weight as they were formed in the experiments.

Although in 58 and 59, as in all other experiments, little or no coke formation occurred, the oils, as far as their bromine value was concerned, and the gases, on account of their great percentage of heavy hydrocarbons, showed these experiments to be inferior to the rest.

The difference was greatest with those experiments where, according to Bergius, heating was carried out with hydrogen under high pressure, namely in 55 and 57, but especially with experiment 52, where a very high hydrogen pressure was reached.

In 52, not less than 34 liters of hydrogen were consumed, in 55 and 57 more than 20 liters. If we compare this with experiments 60 and 61, it appears that in this connection *a high hydrogen pressure is necessary*. The oils of experiments 60 and 61 have a higher bromine value and a higher specific gravity, while it appears from the gas analysis of experiment 61 (the gas of experiment 60 was lost) that practically no hydrogen had been consumed; 7·6 liters of hydrogen were added and 7·7 liters were recovered. In cracking experiment 56, which can be compared with these, 1·3 liters of hydrogen were formed. *Neither does hydrogen in status nascens offer any improvement* in this respect, as appears from experiments 62 and 63, where mixtures of CO and H_2O were used [3].

[1] H. I. Waterman and H. J. W. Reus. The cracking process of Burton, Rec. Trav. Chim. des Pays-Bas **43** (1924), 87.

[2] N. Ipatiew. Polymerisation der Äthylen Kohlenwasserstoffe bei hohen Temperaturer und Drucken, Berichte **44**, 2978 (1912).

[3] This confirms a research by H. I. Waterman and F. Kortlandt: "The treatment of Mexican asphalt and paraffin wax by heating under high pressure

Cracking of Paraffin (200 Gr.).

No.	Time required to reach the temp. (min.).	Duration of the exp. after the reaction temp. had been reached (min.)	Reaction temperature (average, °C.)	Pressure at the beginning of the experiment (Kg./cm²).	Max. pressure during the experiment (Kg./cm²).	Pressure after complete cooling (Kg./cm²).	Products obtained. In Grammes: Oil.	In Grammes: Gas.	Litres: Gas.	Sp. gr. of the oil at 15°C.	Distillation of the oil poured out (Engler): Gasoline[3] (up to 220°) Gr.	Kerosene 220—300° Gr.	Residue 300° Gr. &	Sp. gr. residue 15°/15°.	Bromine value (addition): Oil obtained.	Gasoline	Kerosene	Litres of gas added before the experiment.[1]: CO_2	Heavy hydrocarbons.	O_2	CO	H_2	Other hydrocarbons (CH_4 etc.)	N_2	Litres of gas recovered after the experiment.[5]: CO_2	Heavy hydrocarbons.	O_2	CO	H_2	Other hydrocarbons (CH_4 etc.)	N_2	
52	35	60	450°	110	219	87	177	27·5	93	0·735	98·2	35·0	43·8	0·837	14·5	19·3	9·5	—	—	0·3	—	113·2	—	—	—	0·9	—	—	79·3	9·3	3·5	Hydrogen under high pressure; Heating in a closed vessel.
55	40	60	450°	60	142	50	172	33·8	61	0·745	109·2	31·8	31·0	0·846	22·1	28·4	13·7	—	—	0·1	—	63·9	—	—	—	1·3	0·6	—	40·4	16·4	2·3	
57	25	60	452°	60	140	50	173	32·4	60·5	0·744	104·4	34·2	34·4	0·841	21·1	28·9	13·6	—	—	0·1	—	63·9	—	—	—	1·6	0·2	—	41·3	15·7	1·7	
60	30	60	451°	7	65·5	—	173	—	—	0·769	100·2	33·6	39·2	—	23·8	34·5	15·7	—	—	—	—	7·6	—	—	The gas of this experiment was lost							Hydrogen under low pressure
61	29	60	450°	7	59	13	177	17·5	19·5	0·769	92·0	35·6	49·4	—	25·0	38·3	16·8	—	—	—	—	7·6	—	—	—	1·4	0·2	—	7·7	9·3	0·9	
53	40	60	450°	75	189·5	59	174	75·2	87	0·769	97·8	34·2	42·0	0·883	26·4	35·9	15·9	0·6	3·5	1·2	1·0	4·0	77·3	9·0	1·3	2·5	0·3	0·8	5·1	74·6	2·4	Methane under high pressure
54	48	60	451°	60	162	61	174	77·4	91	0·772	99·1	35·0	39·9	0·883	23·6	35·6	14·4	0·4	2·6	1·0	0·8	3·0	58·9	6·8	—	2·1	0·8	1·0	2·8	77·0	7·3	
62	31	60	451°	23	117	32	176[4]	47·5	41	0·767	96·1	36·6	43·3	—	24·9	37·8	16·5	—	—	0·1	23·5	0·4	not determined	not determined	6·6	1·3	0·3	14·5	6·4	10·3	1·6	$CO+H_2O$ in equivalent quantities
63	40	60	450°	23	116	31·5	180[4]	51·4	43·8	0·765	97·7	35·9	46·4	—	25·1	37·9	16·5	—	—	0·1	23·0	0·4	not determined	not determined	7·1	1·3	0·2	15·8	7·6	10·7	0·9	
64	33	60	451°	60	172·5	66	176	96·7	80	0·768	98·3	34·7	43·1	—	23·7	35·4	16·1	—	—	1·9	—	—	—	65·1	1·0	0·8	0·3	—	1·4	11·0	65·5	Nitrogen under high pressure
56	32	60	449°	0	49·5	8·8	171	23·2	18	0·763	95·6	32·0	43·4	9·875	28·7	41·5	16·9	—	—	—	—	—	—	—	—	3·6	0·2	—	1·3	11·7	1·3	Cracking under its own pressure
58	30	60	450°	0	7	0	133[2]	30	19·5	0·750	85·3	23·0	24·7	0·866	63·2[4]	86·4	29·7	—	—	—	—	—	—	—	0·2	6·8	0·3	0·1	1·2	8·0	2·9	Cracking under constant pressure (7 atm.)
59	31	60	450°	7	7	0	161[2]	44·6	29·5	0·773	77·2	27·1	56·9	0·850	45·9[4]	78·0	26·5	—	—	—	—	—	—	14·0	0·1	5·9	0·2	—	1·0	6·8	15·5	

[1] Saturated with water.
[2] In these experiments oil losses were great.
[3] Including losses caused by evaporation during the distillation.
[4] The oil obtained is here a mixture of distillate and oil poured out of the autoclave in the true proportion by weight.

[5] The gas present in the autoclave before and after the experiment (about 1 litre) has not been taken into account. In all experiments except 56, the autoclave was forced up first and then blown off and the gas measured, after which it was forced up again. Consequently practically no air is present. In 58 the air was driven out by nitrogen before the experiment.

In these experiments the CO_2 and hydrogen, formed according to the equation $CO+H_2O \rightarrow CO_2+H_2$, were present in the reaction gases in nearly equivalent quantities, namely, 6·6 and 7·1 liters of CO_2, with respectively 6·4 and 7·6 liters of hydrogen.

In the corresponding experiment 56, already mentioned, 1·3 liters of hydrogen were formed.

As in 60 and 61, it appears that in 62 and 63 no important hydrogen consumption took place. In this respect there is no difference for paraffin between hydrogen under low pressure and hydrogen formed during the experiment by the reduction of water by CO.

An indifferent gas under high pressure, such as nitrogen (64) and high pressure technical methane (53 and 54), does not have a favourable influence.

We find that in 64 the amount of nitrogen added remained unchanged, while in 54 the total volume of hydrocarbons in the reaction gases was only slightly changed. Experiment 53 seems to point to a decrease, possibly pronounced. The results of the gas analysis (percentage N_2), the low pressure after complete cooling and the low yield of gas, however, point to a small leak that probably arose during the cooling. Furthermore, one sees that in 54 the hydrogen present in the methane as an impurity is recovered after the experiment.

If we compare the experiments with hydrogen under high pressure (52, 55 and 57), hydrogen under low pressure (60 and 61), methane under high pressure (54), hydrogen in *status nascens* ($CO+H_2O$, 62 and 63) nitrogen under high pressure (64) and simple heating in a closed autoclave only under the pressure of the gases that develop during the heating (56) then it appears that:

1. The yield of oil, in respect of gasoline, kerosene and residue is practically the same in all these experiments.

From this it appears that the yield of gas ought to be practically the same, too.

2. Experiments 52, 55, and 57, with hydrogen under high pressure, distinguish themselves in a favourable sense, *i.e.*:

A. A better appearance and a lower specific gravity of the oil.

B. A lower bromine value (addition) of the gasoline and kerosene.

If we compare 60 and 61, 53 and 54, 62 and 63, 64 and 56 on the one hand, with 58 and 59 on the other (in the latter two experiments distillation took place during the heating while the pressure was kept constant at seven atmospheres), then it appears that:

(*a*) The yield of gas was greater in 58 and 59. The yield of oil

with sodium formate and with carbon monoxide and water respectively," Rec. trav. chim. des Pays-Bas **43**, p. 249 (1924).

is consequently lower, even if (in 58 and 59) there had not been any losses.[1]

(*b*) The gas of 58 and 59 contained much heavy hydrocarbon.

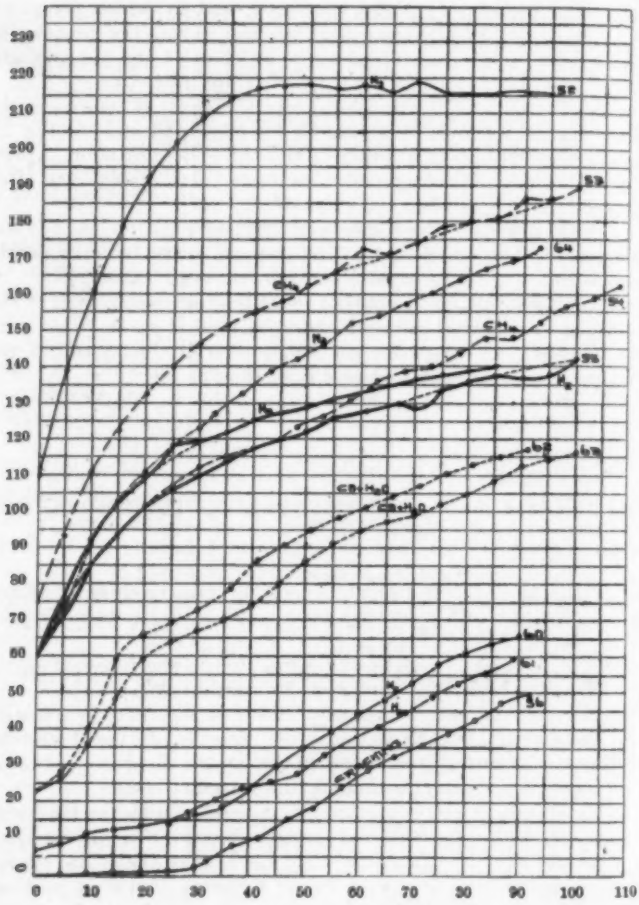

FIG. 2.

[1] One has to reckon with the fact that in 58 the experiment was started without any pressure, while experiment 59 was started after the nitrogen pressure amounted to seven atmospheres.

(*c*) The bromine value of the oil of 58 and 59 is extraordinarily high.

The heating in a closed autoclave or the heating in one which has been filled before with a little hydrogen, methane or nitrogen under high pressure or with $CO(+H_2O)$, and by which pressures of 50 atmospheres and higher were reached during the heating, is consequently better than a heating by which one keeps the pressure constant at 7 atmospheres and distils in the meantime.

A consideration of the graphical representation of the change in pressure in 52, 55 and 57, 60, 61, 53, 54, 62, 63, 64 and 56 (Fig. 2) shows that, with the exception of the three Berginisation experiments 52, 55 and 57, the pressure increases considerably even after the temperature has become constant.

In cases where hydrogen has been consumed (52, 55 and 57) the curve is absolutely different. The pressure curve becomes nearly horizontal in 52 where most hydrogen has been consumed.

As explained before, we cannot enter into an explanation of the course of the pressure curves because at present we have no clear understanding of the nature of the reaction products, and of the chemical reactions taking place during the process.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

By George Sell, Assistant Editor.

In preparing the first Annual Report on the Progress of Naphthology it has been thought desirable to place on record the history of the Institution from the time of its conception.

The foundation of the Institute was due to the foresight of the late Sir Boverton Redwood and Mr. Arthur W. Eastlake who, realising the need of some means of bringing together the scientists and others engaged in the various branches of the Petroleum Industry, and with the assistance of the late Mr. Leonard V. Dalton, prepared a scheme for the foundation of such a body.

A number of gentlemen intimately connected with the Petroleum Industry were approached, and agreed to become Founder Members. On November 7th, 1913, a meeting was held at the Royal Society of Arts, the chair being taken by Sir Boverton Redwood, who was elected as First President, and the various officers of the Institution were appointed. The Rt. Hon. Lord Cowdray, of Midhurst (now Viscount Cowdray of Cowdray), was elected as Vice-President, Sir William Plender as Honorary Treasurer, Sir Frank Crisp, Bart., as Honorary Solicitor, and Messrs. Leonard V. Dalton and Sidney H.

North as Joint Honorary Secretaries. The first Council was also elected at this meeting, and office accommodation was offered by Mr. Arthur W. Eastlake at 17, Gracechurch Street, London, E.C.

At a Council Meeting held on November 14th, 1913, Dr. David T. Day and Dr. C. Engler were elected as Honorary Members and on December 11th, 27 Members, 18 Associate Members, 3 Students, and 2 Associates were elected as Original Members.

The Inaugural Meeting of the Institution was held at the House of the Royal Society of Arts on March 3rd, 1914, and short addresses were given by Sir Boverton Redwood, Sir Thomas H. Holland, Professor Vivian B. Lewes, and Mr. E. H. Cunningham-Craig.

In April, 1914, Mr. Leonard V. Dalton resigned his position as Honorary Secretary, owing to ill health, and Dr. W. Hope Henderson was appointed to that post.

The Licence and Certificate of Incorporation were obtained from the Board of Trade, dated April 17th, 1914.

In June, 1914, the first number of the JOURNAL, containing the papers read at the Inaugural Meeting, the Memorandum and Articles of Association and the By-Laws, and the List of Members was issued, and publication continued thereafter at regular intervals.

Dr. W. Hope Henderson resigned from the Honorary Secretaryship in September, 1914, and Mr. F. G. Palmar was appointed as Assistant Secretary, and Messrs. Price, Waterhouse and Company kindly agreed to act as Honorary Auditors.

In January, 1915, Mr. Arthur W. Eastlake was appointed as Honorary Secretary, Mr. W. H. Dalton as Honorary Editor and Librarian, and Sir Boverton Redwood was re-elected as President.

In February, 1916, Sir Thomas H. Holland was elected as President, but his official duties rendered it impossible for him to accept the position, and Professor John Cadman (now Sir John Cadman), was elected as President for the Session.

During 1916 a Sub-Committee on the Desulphuring of Shale Oil was formed, and members were appointed to the Oil Shale Resources Committee of the Committee of the Privy Council for Scientific and Industrial Research.

In September, 1916, military duties having claimed the services of the then Acting-Secretary (Mr. F. G. Palmar), Mr. W. Rogers was appointed to fill the position.

In 1917, Mr. Charles Greenway (now Sir Charles Greenway) was elected President, and Sir John Cadman was appointed to represent the Institution on the Conjoint Board of Scientific Societies.

Sir Charles Greenway was re-elected President in March, 1918, and in that year a Committee was appointed to enquire into the Cannel Coal Resources of Great Britain. Mr. Arthur W. Eastlake

was appointed as the Institution's representative on the Conjoint Board of Scientific Societies. A suggestion was put forward for the formation of a Standardization Committee, but owing to the War this was postponed.

The President for the Session 1919–1920 was Sir Frederick W. Black, and in 1919 it was decided to hold the First Annual Dinner, which took place at the Connaught Rooms, Great Queen Street, London, on March 25th, 1919.

On June 4th, 1919, the Institution suffered an irreparable loss in the death of its Founder and First President, Sir Boverton Redwood.

During the year the Institution was represented on the Committee appointed to consider matters arising in connexion with the extended use of Fuel Oil in the Mercantile Marine. The Final Report of the Cannel Coal Committee was also approved in 1919.

In 1920 Sir F. W. Black was re-elected President, Dr. A. E. Dunstan was appointed Honorary Assistant Editor, and Mrs. A. Lloyd Eastlake as Librarian. In the summer of 1920, owing to the death of Mr. W. Rogers, the Acting Secretary, Mr. George Howell was appointed in his stead.

In February, 1920, the offices of the Institution were removed from 17, Gracechurch Street, to 5, John Street, Adelphi, London, larger accommodation having been secured there.

It was decided that the Institution should take part in the Petroleum Exhibition at the Crystal Palace, 1920, and arrange for a series of lectures to be given by its members. These lectures were subsequently published in book form under the title of "The Petroleum Industry."

The British Engineering Standards Association having asked for representatives from the Institution, these were duly appointed.

Professor J. S. S. Brame was elected as President for the Session 1921–1922, and Dr. A. E. Dunstan was appointed Honorary Editor, Mr. W. H. Dalton having resigned from that position. In August, 1921, Commander R. E. Stokes-Rees, R.N., was selected from a large number of applicants as Secretary and Librarian, Mrs. A. Lloyd Eastlake and Mr. George Howell having resigned their respective positions as Librarian and Secretary.

The Standardization Committee was appointed on May 30th, 1921, and by the end of the year was actively engaged in carrying out its work.

Representatives were appointed to the Committee of Birmingham University, which is responsible for the education of Petroleum Technologists, and to the Fuel Economy Committee of the British Association for the Advancement of Science.

Professor J. S. S. Brame was re-elected President in 1922, and early in that year the membership exceeded the total of 500 for

which the Board of Trade Licence had been obtained. Application was made and granted for the number to be extended to 1000. The Institution joined the American Society for Testing Materials, and representatives also attended the International Congress on Liquid Fuels in Paris.

During the year (1922) it was decided to offer a prize of five guineas and a medal to the Student presenting the best paper during any session.

Mr. Herbert Barringer was elected as President for the session 1923–1924.

Early in 1923 it was found that the accommodation at No. 5, John Street, was rapidly becoming inadequate for the increasing membership of the Institution and its library. Larger and more suitable premises were eventually obtained at Aldine House, Bedford Street, Strand, London, and the move into these took place at the end of June. A description and photographs of the new offices was published in JOURNAL 38 (August, 1923), and subsequently a House Warming and Exhibition of Scientific Apparatus was held there on October 3rd, 1923.

During the year the Institution was asked to appoint representatives on the International Air Congress, the British Empire Exhibition, 1924 (Chemical Section), the 3rd Congress Société de Chimie Industrie, the Empire Mining and Metallurgical Congress, and at the 6th International Mining Exhibition, Agricultural Hall, where it had a stand and arranged a Petroleum Conference. A representative attended the International Petroleum Exposition and Congress at Tulsa, Oklahoma.

During the year the Standardization Committee completed its work, the results of which are now published in book form.

It is with pleasure that we have to record the presentation to the Institution by Mr. Robert Redwood of the original Redwood Viscometer, the instrument which was first used by the late Sir Boverton Redwood in inventing his well-known apparatus.

One of the outstanding items of progress in 1923 was the foundation of the Students' Section, with its two branches, London and Birmingham, both of which have held several meetings at which papers have been read. In this connexion the Institution is indebted to the Anglo-American Oil Company for their generosity in presenting the sum of £100 to be used as prizes for Students.

From the following table it will be seen that the progress of the Institution has been continual. Even the war, which commenced so soon after the foundation of the Institution, did not prevent its membership increasing year by year. As would be expected, development during the war was on a small scale, but the post-war years have been marked by the large increase in the numbers of new members elected. It is interesting to record here that during the

war only one Meeting had to be abandoned, and that on account of an air raid being in progress at the time.

MEMBERSHIP AT DECEMBER 31ST.

Year.	Honorary Members.	Members.	Associate Members.	Students.	Associates.	Total.
1913 ..	2	56	16	2	8	84
1914 ..	2	92	48	15	8	165
1915 ..	4	105	54	17	9	189
1916 ..	3	125	59	19	11	217
1917 ..	5	126	63	20	10	224
1918 ..	7	145	71	20	11	254
1919 ..	7	169	81	19	11	287
1920 ..	7	229	93	35	23	387
1921 ..	8	276	125	55	34	498
1922 ..	8	311	138	68	36	561
1923 ..	9	340	165	110	32	656

The Institution may be said to be international, having members in every clime, as will be seen from the List of Members.

Attendance at the meetings is worthy of note, the average during 1923 being 73 Members and 37 Visitors, especially when it is realised that a large number of the members are non-resident in England.

With regard to the JOURNAL, while Volume I. (1914–1915) contained 324 pages, Volume 9 (1923) has 482 pages of Transactions and 337 pages of Abstracts and Current Bibliography. Until 1921 each Volume was issued in four numbers, in 1921 and 1922 in five and in 1923 it became necessary to publish in six numbers per volume. In addition to papers read before the Institution, a number of contributed articles are published, and from Journals 23 and 29 respectively, a Bibliography of Current Literature and Abstracts of Articles and Patents have been included in each issue. Firms engaged in the Petroleum Industry are finding the Journal an excellent advertising medium and the services of an Advertising Agent have been found necessary. While 500 copies of each issue of the early Journals was sufficient to meet current needs, it is now necessary to print 1200 copies, and numerous applications are received for back numbers.

The social side of the Institution has not been neglected. The Annual Dinner is now an event anticipitated by all members and their friends, and the attendance at each Dinner exceeds that at the preceding one. The Dinner Club, under the able guidance of Mr. Ashley Carter, continues to hold its informal dinners after each General Meeting, these gatherings taking place at the Chemical Industry Club.

Members visiting London are always sure of a cordial welcome at the Institution's offices, and a special room is reserved where they may write letters or meet and converse with their friends. The Library is well supplied with current petroleum periodicals, and as far as possible with all the books published dealing with the petroleum industry or any particular phase thereof.

Statistics.

By Arthur W. Eastlake, M.I.Min.E., A.M.I.Mech.E.

World's Production of Crude Oil.—The table given below shows the World's Production of Crude Oil by countries for the years 1921 to 1923. While it is exceedingly difficult to obtain reliable figures of the annual output of the various countries until some considerable time, often nearly two years, after the year to which they refer, those given for 1923 may be taken as a guide, being based in the majority of cases on preliminary returns as published. (See page 683).

From the table it will be seen that the world's production continues to increase, that for 1922 being about 11 per cent. more than 1921, and 1923 about 18 per cent. higher than 1922, or practically double that of 1918 (67,731,470 metric tons).

The percentage produced by each country in 1923 remains materially the same as in 1922, the variation in most instances being small. The United States may be noted as having increased its percentage production by about 7 per cent., while Mexico decreased by about 7 per cent. The percentage produced by the British Empire continues to show a slight decline, being 1·885 in 1921, 1·811 in 1922, and 1·669 in 1923, the only actual percentage increase being in the case of Sarawak, although Trinidad increased its production by about 24,000 metric tons as compared with 1922.

The United States of America.—The table given below, the figures for which have been extracted from the returns published by the United States Geological Survey, gives details of the crude petroleum production and consumption in the United States for 1923. Comparative figures for 1922 are also given. (See opposite).

Production.—It will be noted that the total production of crude in 1923 exceeded the 1922 figure by 31 per cent. The most noteworthy increase during the year was that of the State of Arkansas, which rose from 12,712,000 barrels in 1922 to 36,610,000 barrels in 1923. This increase is accounted for by the locating of prolific fields at El Dorado and Smackover. The next highest increase is that of California, due to important discoveries in the Elk Hills, Santa Fe Springs, Long Beach and Huntington Beach districts. Wyoming also showed an increase of 68 per cent. over the 1922 production.

Stocks on Hand.—With the exception of the Gulf Coast Field and Imported Oil, the stocks on hand at the end of the year were

UNITED STATES OF AMERICA.

Production and Consumption of Petroleum 1922 and 1923.

In Barrels of 42 U.S.A. Gallons.

Fields and States.	Production. 1922.	Production. 1923.	Percentage increase or decrease 1923 compared with 1922.	Net Pipe-line and Tank-farm Stocks on Hand. Dec. 31st, 1922.	Net Pipe-line and Tank-farm Stocks on Hand. Dec. 31st, 1923.	Deliveries to Consumers. 1922.	Deliveries to Consumers. 1923.
APPALACHIAN:							
New York	1,000,000	1,250,000	+ 25				
Pennsylvania	7,425,000	7,609,000	+ 2				
West Virginia	7,021,000	6,358,000	− 10	5,941,000	6,331,000	—	
Eastern and Central Ohio	4,751,000	4,931,000	+ 4				
Kentucky	8,973,200	8,069,000	− 10	2,927,000	2,879,000	—	
Tennessee	9,800	8,000	− 18				
	29,180,000	28,225,000	− 3	9,279,000 *a*	9,716,000 *b*	27,184,000	27,788,000
LIMA-INDIANA:							
North-west Ohio	2,030,000	2,154,000	+ 6	—	—	—	—
North-east Indiana	239,000	250,000	+ 5	—	—	—	—
	2,269,000	2,404,000	+ 6	742,000 *c*	1,020,000 *d*	2,589,000	2,126,000
ILLINOIS AND SOUTH-WEST INDIANA:							
Illinois	9,383,000	8,707,000	− 7	—	—	—	—
South-west Indiana	848,000	793,000	− 7	—	—	—	—
	10,231,000	9,500,000	− 7	10,306,000 *e*	11,243,000 *f*	7,649,000	8,563,000
MID-CONTINENT:							
Oklahoma	149,571,000	160,929,000	+ 8				
Kansas	31,766,000	28,250,000	− 10	136,601,000	171,781,000	—	
Central and North Texas	83,314,000	100,202,000	+ 20				
North Louisiana	33,629,000	22,469,000	− 33	15,972,000	31,123,000	—	
Arkansas	12,712,000	36,610,000	+188				
	310,992,000	348,460,000	+ 12	158,668,000 *g*	210,077,000 *h*	257,838,000	297,051,000
GULF COAST:							
Coastal Texas	35,370,000	30,821,000	− 13	—	—	—	—
Coastal Louisiana	1,747,000	2,450,000	+ 40	—	—	—	—
	37,117,000	33,271,000	− 10	25,796,000 *i*	24,964,000 *j*	30,037,000	34,103,000
ROCKY MOUNTAIN:							
Wyoming	26,715,000	44,785,000	+ 68	—	—	—	—
Colorado	97,000	86,000	− 11	—	—	—	—
Montana	2,449,000	2,782,000	+ 13	—	—	—	—
	29,261,000	47,653,000	+ 63	2,675,000 *k*	20,688,000 *l*	28,487,000	29,640,000
CALIFORNIA	138,468,000	262,876,000	+ 90	49,375,000	62,162,000	124,115,000	250,089,000
OTHER	13,000	18,000	+ 40	—	—	13,000	18,000
TOTAL	557,531,000	732,407,000	+ 31	256,841,000 *m*	339,870,000 *n*	477,912,000	649,378,000
IMPORTED OIL*	127,308,000	82,015,000	− 36	5,062,000	4,754,000	124,515,000	81,999,000
EXPORTS OF IMPORTED OIL	—	—	—	—	—	168,000	324,000
GRAND TOTAL	684,839,000	814,422,000	+ 19	261,903,000	344,624,000	602,595,000	731,701,000

* Including some topped oil.

a Including 411,000 barrels producers' stock.
b „ 506,000 „ „ „
c „ 57,000 „ „ „
d „ 45,000 „ „ „
e „ 166,000 „ „ „
f „ 152,000 „ „ „
g „ 6,095,000 „ „ „
h Including 7,173,000 barrels producers' stock.
i „ 1,015,000 „ „ „
j „ 990,000 „ „ „
k „ 684,000 „ „ „
l „ 984,000 „ „ „
m „ 8,428,000 „ „ „
n „ 9,850,000 „ „ „

WORLD'S PRODUCTION OF CRUDE PETROLEUM.

WORLD'S PRODUCTION OF CRUDE PETROLEUM.
In Metric Tons.

Country.	1921. Production.	1921. Percentage of total.	1922. Production.	1922. Percentage of total.	1923. Production.	1923. Percentage of total.
United States	62,957,700	61·656	74,337,500	65·379	97,654,300	72·652
Mexico	25,786,300	25·253	24,303,800	21·375	19,937,200	14·833
Russia	4,000,000	3·917	4,500,000	3·958	5,200,000	3·869
Persia	1,919,700	1·880	2,525,000	2·221	3,213,600	2·391
Dutch East Indies	2,295,500	2·248	2,283,000	2·008	2,048,000	1·524
Rumania	1,163,800	1·140	1,367,500	1·203	1,508,800	1·123
Galicia	704,900	0·690	713,100	0·627	736,600	0·548
Argentina	322,000	0·315	450,200	0·396	530,000	0·394
Venezuela	215,000	0·211	304,000	0·267	525,000	0·390
Peru	475,700	0·466	483,000	0·425	487,000	0·362
Japan and Formosa	248,900	0·244	246,200	0·217	241,000	0·179
France	55,600	0·054	77,100	0·068	70,700	0·053
Germany	36,700	0·035	45,000	0·040	25,700	0·019
Italy	4,800	0·005	4,700	0·004	4,700	0·003
Other Countries	1,500	0·001	1,700	0·001	2,000	0·001
British Empire:						
India	1,191,200	1·167	1,123,800	0·988	1,122,000	0·835
Sarawak	203,000	0·199	409,800	0·360	580,000	0·432
Trinidad	314,000	0·308	326,000	0·287	350,000	0·260
Egypt	189,900	0·186	176,100	0·155	153,500	0·114
Canada	25,600	0·025	24,400	0·021	24,400	0·018
United Kingdom	300	—	100	—	—	—
Total	102,112,100	100·000	113,702,000	100·000	134,414,500	100·000

in excess of those at the end of 1922, the total being an increase of 31 per cent. over the previous amount.

Consumption.—The consumption of crude, as indicated by the quantity delivered to consumers, was 21 per cent. higher than in 1922, the consumption of Californian crude showing the remarkable increase of 102 per cent.

While the quantity of imported oil consumed in the country decreased by 34 per cent., the amount of that oil re-exported was nearly doubled.

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STUDENTS' SECTION, LONDON BRANCH.

THE Sixth Ordinary Meeting of the Students' Section, London Branch, was held at Aldine House, Bedford Street, Strand, W.C. 2, on Tuesday, April 29, 1924.

Owing to the unavoidable absence of the Chairman, the Chair was taken by Mr. H. S. Garlick, Vice-chairman of the Section.

An abstract of the paper read follows :—

Fuller's Earth and its Application to the Petroleum Industry.

By A. RAUCH, A.R.C.Sc. (member) and G. E. PAIN, A.R.C.Sc. (non-member).

Fuller's earth is extensively used in the oil industry as a decolorising medium. Its importance in these industries can scarcely be over-estimated. Recent figures of the amounts of fuller's earth used per annum are not available, but as far back as 1912 the animal and vegetable oil industries alone used as much as 25,000 tons, and a far greater amount was used for mineral oils.

It is found in England at Redhill and in Gloucestershire, in the U.S.A. in Texas, Arkansas and Florida, in Germany and other countries, but is mined on an extensive scale mainly in England and U.S.A.

In England the material is dug and separated from small stones and sand by elutriation. After this it is dried, crushed and graded into sizes of 15–30, 30–60, 60–80, etc. mesh. In this process about 15 per cent of the earth becomes too finely powdered for use and must be discarded. Following figures show percentages of sizes obtained from a plant taken from a paper by C. L. Parsons, *U.S. Bureau of Mines Bull.*, 71, 1913 :—

Mesh.	Per cent.	Mesh.	Per cent.
15–30	13·7	80–180	5·25
30–60	40·4	170 up	0·09
60–80	6·0	60–110	0·04
60 up	11·9	Fine waste	18·40
100 up	4·2	Total	99·98

The figures below, taken from the paper by C. L. Parsons, show the variation of filtration velocity with method of grinding :—

Origin of sample.	Method of grinding.	Time of filtration. Minutes.	Condition of residue.
Summerville, Tex. ..	Coffee mill	.. 5·5 ..	Mealy
England	„	.. 5·0 ..	Quite dry
Pikes Peak, Ga. ..	„	.. 4·5 ..	„
Midway, Fla. ..	„	.. 5·0 ..	„
Klondike, Ark. ..	„	.. 12·0 ..	Fairly dry
Summerville, Tex. ..	Agate mortar	.. 10·5 ..	Rather oily
England	„	.. 10·0 ..	Fairly dry
Pikes Peak, Ga. ..	„	.. 45·0 ..	Very oily
Midway, Fla. ..	„	.. 30·0 ..	„
Klondike, Ark. ..	„	.. 29·0 ..	„

The colour of fuller's earth may be brownish, bluish, greyish, cream, pink, and even black. Its specific gravity varies between 1·75 and 2·5, while its hardness covers all graduations from very hard to very soft.

In a paper by Engler and Albrecht, published in the *Zeit. ang. Ch.*, 1901, an account is given of an investigation of the selective action of a column of fuller's earth on a crude oil, whose appearance was brown, translucent with a green fluorescence, and a sp. gr. of 0·7905 at 18° C. or 0·7929 at 15° C. The oil was contained in a reservoir and led to the bottom of the column of fuller's earth, filtration taking place upwards, fractions being taken from the top, and the results are shown below :—

Fracn.	Found sp. gr.	Sp. gr. at 10° C.	Appr. Amnt. c.c.	Appearance.
1	0·7780 at 19·0° C.	0·7812	70	Waterwhite
2	0·7822 at 21·0	0·7870	65	Waterwhite with pale fluorescence
3	0·7849 at 21·0	0·7897	120	„
4	0·7857 at 21·0	0·7905	70	„
5	0·7885 at 18·5	0·7913	50	„
6	0·7887 at 19·0	0·7919	110	Pale yellow with green fluorescence
7	0·7900 at 17·5	0·7920	100	A little darker yellow
8	0·7945 at 17·5	0·7965	400	Yellow with green fluorescence
9	0·7985 at 20·0	0·8020	50	„
10	0·8004 at 19·0	0·8032	100	„
11	0·7952 at 18·0	0·7976	300	Orange with greenish fluorescence
12	0·7938 at 18·0	0·7962	500	„

By using six side tubes placed at regular intervals all up the column of earth they proved that the lighter fractions rushed to the top, while the heavier ones stayed more and more behind.

The following figures given in the *U.S. Bureau of Mines Bull.*, 71, 1913, were obtained from aliquot portions of five barrels each in

an actual run of a hundred barrels spindle oil through twenty-five tons of fuller's earth :—

Barrels.	Saybolt Visc.	Setting pt. ° F.	Barrels.	Saybolt Visc.	Setting pt. ° F.
1–5	187	31·5 ..	60–65	275	27·1
5–10	220	29·7 ..	65–70	275	27·1
10–15	242	28·6 ..	70–75	277	27·0
15–20	253	28·2 ..	75–80	277	27·0
20–25	260	27·9 ..	80–85	278	27·0
25–30	265	27·6 ..	85–90	278	27·0
30–35	266	27·5 ..	90–100	278	27·0
35–40	268	27·3 ..			
40–45	271	27·3 ..	Aver. 1–25	224	29·6
45–50	273	27·2 ..	„ 1–50	246	28·4
50–55	274	27·2 ..	„ 1–75	258	28·0
55–60	274	27·1 ..	„ 1–100	259	27·8

Probably the most peculiar property of the southern U.S. earths is their so-called "acidity." Suspensions of fuller's earth in water show an acid reaction towards litmus and phenolphthalein, although apparently no free acid is present. This acidity can be treated with alkalies. For example, 2 g. of fuller's earth suspended in a 100 cc. of distilled water and titrated with N/10 NaOH solution, gave results varying between 0 and 230 cc. of H/10 NaOH solution per 100 g. of fuller's earth. It has been suggested that the basis of this peculiarity is silicic acid. It is a notable fact that samples of fuller's earth showing a high degree of acidity possess a greater bleaching power than those of low acidity. But, on the other hand, the bleaching power of a sample of fuller's earth is not directly proportional to its acidity. Lime water treatment would destroy the acidity and at the same time the decolorising power. The latter can, however, be restored by acid treatment of the earth.

When a suspension of a sample of fuller's earth showing a high acidity is subjected to the action of an electric current the grains of fuller's earth act like a negatively charged colloid, inasmuch as they migrate to the positive electrode.

Fuller's earth is capable also of absorbing basic colours from solution in water. If these dyes are extracted from the earth again their colour is found to be that of their respective acid salts.

In a paper by L. G. Gurvitsch, abstracts of which were published in the *J.C.S.*, 1915, the action of floridine on unsaturated compounds is dealt with. It is a notable fact that when the resinous colouring matter, removed from petroleum by floridine, is extracted by ether, the latter evaporated off, and the residue added to the original decolorised petroleum, the resultant solution is darker than the untreated petroleum. Since there is nothing in floridine which can be extracted by ether, this result must have been brought about by some chemical change of the aforesaid colouring matter, and the only available agent through which this change could be effected is the floridine.

Gurvitsch found that on mixing freshly rectified amylene, b.pt. 39–40·5° C., with an equal weight of dehydrated floridine a considerable rise in temperature occurred. After standing for two days about 65 per cent. of polymerised products, b.pt. above 100° C., were formed, consisting largely of the diamylene obtained by action of sulphuric acid on amylene. Similarly 5 per cent. floridine causes pinene to boil vigorously, and by careful treatment 6–7 per cent. of camphene calculated on the original pinene was obtained. A later investigator failed to obtain any camphene at all, but noticed the presence of dipinene and other polyterpenes.

A microscopical examination of fuller's earth shows an internal crystalline structure of a very complex nature. It is probable that it is in the interstices between the minute crystals in a grain that the decolorising takes place. If we examine freshly heated earth through the microscope it appears translucent with a dark brown core, whereas in exhausted earth the grains appear completely black, as if filled with some dark substance.

Fuller's earth consists chiefly of quartz and aluminium silicate, containing almost always ferrous and ferric oxides and less often magnesia, lime and traces of alkalies. It contains also water, both combined and as moisture. The figures below show some analyses of different samples of fuller's earth taken from a paper by D. Wesson, *Mining and Eng. World*, 1912, 37, 667 :—

Constituent.	English "S.L." Per cent.	English "C.L." Per cent.	Duck Hill, Miss. Per cent	Duck Hill, Miss. Per cent.	Grenada, Miss. Per cent.	"X.L." Per cent.	Quincy, Fla. Per cent.
Silica ..	64·00	64·50	78·00	78·35	74·15	65·60	63·90
Alumina ..	17·46	15·02	13·18	14·50	16·86	13·12	27·80
Ferric oxide	11·40	12·80	7·35	6·30	5·82	12·83	3·40
Lime ..	3·05	3·46	1·57	0·85	0·36	6·58	2·42
Magnesia ..	4·09	3·86	trace	—	1·51	1·64	2·42
NaCl ..	—	0·20	—	—	—	—	—
	100·00	99·84	100·00	100·00	98·70	99·77	100·00
H_2O at 100°	12·05	13·85	8·50	9·22	—	24·00	17·40
Total H_2O ..	18·96	20·90	16·23	16·44	27·77	—	—

Apparently the bleaching power of fuller's earth does not depend on its chemical composition, because slight and even big variations in the analyses of the earth do not seem to have any influence on the bleaching power. In using fuller's earth, the main purpose is to get the lightest possible colour with the longest use of the earth. The following facts must, therefore, be borne in mind :—

(1) The longer the column of earth the better the bleach and the lighter the colour of the oil, other conditions being equal.

(2) The coarser the earth the more rapid the flow and the poorer the bleach, other conditions being equal.

(3) The higher the temperature the faster the flow and the poorer the bleach, other conditions being equal.

(4) As a corollary, filtration should take place at the lowest temperature at which the oil works well.

(5) The oil which is being filtered must be fluid enough to be acted on mechanically by the internal structure of the pores of the fuller's earth, for it is in those pores that the colouring ingredients of the oil are retained, and not in the spaces between the grains themselves.

The preparation of fuller's earth is done by burning, and this is a very important factor in the bleaching power of the earth. During this burning it is necessary to get rid of the water present in the earth, varying between 10 and 15 per cent. Organic and volatile salts are also expelled during this burning. On heating a sample of earth, which was pale brown in colour when unheated, to 500° C., the colour of the earth underwent two changes. When the temperature reached 300° C. the colour of the earth was dark grey, and it lightened in colour as the temperature approached 400° C. On continuing the heating, the colour turned to a brown, which was darker than the original colour of the earth.

The earth ready prepared for use is placed in large cylindrical funnels called percolators, able to hold 25 tons. The oil is filtered through the earth, and the filtered product run into tanks, according to colour. If the oil is very viscous, it is heated just enough to be able to filter it without applying too great pressures. When the earth has become exhausted air is pressed through it in order to get out as much oil as possible. For the same purpose naphtha washing follows the pressing out with air, and the earth is afterwards blown out with steam in order to get out the remaining solution of oil in naphtha.

In order to use the earth again for bleaching of oil, it must be regenerated, and that is done by heating. The exhausted earth is dropped from the bottom of the percolator on to a belt conveyor and carried to a special furnace where it is heated to temperatures up to 600–650° C., depending on the earth and on the practice used in the refinery. Then the earth is conveyed back to the percolator and used again.

In the paper by C. L. Parsons already referred to mention is made of a laboratory method of recovering fuller's earth by extracting as much as possible of the colouring matter with ethyl alcohol, treating the earth with a little acid and re-extracting with alcohol. This method cannot be made use of on a large scale, owing chiefly to the difficulty of recovering the alcohol used. It was suggested that a higher alcohol, such as amyl, would be more satisfactory, both from the point of view of its solvent power and

its immiscibility with water. Among other solvents tried were carbon disulphide, tetrachlorethane and dichlorethylene; it was found in general that the higher the boiling point of a solvent, the greater its efficiency. These solvents were used in an apparatus which is a modification of the Sohxlet extractor, the percolator taking the place of the thimble and the solvent vapours reaching the reflux condenser by means of side tube. The aforementioned results seemed to show that the increase of efficiency was due either to the fact that the condensed vapour of the higher boiling liquids passed through the earth at higher temperatures, or to the fact that their molecular structure more nearly approaches that of the substances it has to extract, or to both. This led to the designing of an apparatus in which the percolator is surrounded by a steam jacket. As a result of this preliminary work, the following working method was arrived at: 25 g. of floridine, which has been subjected to one of the already mentioned treatments—that is, heating to different temperatures—were placed in the percolator which was plugged at the bottom with cotton wool; 50 cc. of a 40 per cent. solution of dark cylinder oil in 80–100° C. petroleum ether was filtered through, of which only about 10–12 cc. were collected, the remainder being retained by the earth. Then, aliquot portions of 25 cc. of the solution were filtered, the filtrates being collected separately, until the bleaching power of the earth was destroyed. Steam at about 6 lb. pressure was passed through the exhausted floridine, thus displacing practically all the oil retained between the grains. Steam was then passed through the jacket and air blown through the earth to remove the condensed water. Then followed an extraction with glacial acetic acid, afterwards blown out, and this again by an extraction with one of the organic solvents. The latter was removed either by blowing with air or by extraction with petroleum ether, depending on the volatility of the solvent. Acid and solvent were alternated for 2–3 times, until no more colouring matter was extracted. Very hot air was then drawn through the earth, which reached a temperature of about 200° C. under this process. This removed the last traces of solvent from the pores. The percolator was allowed to cool and the bleaching power of the recovered earth tested in the same way as was done with the fresh earth. From the results obtained up to the present it is found that the bleaching power is increased after the first recovery, but soon falls to a standard just below that of the fresh earth, where it seems to remain.

It was found that the bleaching power of a sample of fresh earth which had undergone one preliminary treatment with acid and solvent was greater than that of fresh earth heated to either 400° C. or 500° C.

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DISCUSSION.

Mr. Garlick asked whether the author had heard of some work done by Japanese investigators on acid clay. He also asked the author the difference between fuller's earth, bauxite, kieselguhr and acid clay.

Mr. A. B. Miskin remarked on the important use of fuller's earth in the bleaching of lubricating oils, and suggested the use of clay instead of fuller's earth. As an explanation for the electronegativity of some earths, Mr. Miskin suggested the presence of silica, which is electronegative. The presence of carbon dioxide in some of the fuller's earths was explained by Mr. Miskin to be due to the presence of lime. He agreed with the author's remark regarding the increase of the bleaching power of a filtering medium with the angularity of the grains.

Mr. R. F. Owen said that he would like to know the difference between fuller's earth and bauxite, and also why bauxite is sometimes used warm.

Mr. E. H. Cunningham-Craig congratulated the author on the excellent paper he had read. He suggested that the presence of lime and magnesia in the earth lowers the bleaching power, and also gave some details regarding the formation of fuller's earth in nature, and suggested that the presence of carbon dioxide in fuller's earth must be caused by traces of vegetable matter, which is in agreement with the darkening in colour of the earth during the process of heating.

Mr. F. R. S. Henson asked whether the author had heard of the work of Prof. Day regarding the natural migration of oils.

Mr. Mendelssohn stated that fuller's earth had the property of absorbing sulphur compounds and aromatic substances more easily than paraffin hydrocarbons.

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* See also *Colloid Chemistry of Petroleum.* A. E. Dunstan. Third Report on Colloid Chemistry, p. 91. London, H.M. Stationery Office, 1920.

Mr. E. Peel asked a question regarding the price of fuller's earth, and wanted to know whether clays could be used instead of fuller's earth in the cases where the transport costs of the latter were prohibitive.

The Author, in reply to Mr. Garlick, said that he had not heard of the work of the Japanese investigators. With reference to the difference between fuller's earth, bauxite, kieselguhr and acid clay, it was pointed out that there is no definite composition for fuller's earth, and that any substance having a composition similar to those given during the course of the lecture and which possess a certain bleaching power is called by that name. Bauxite is nearly pure aluminium oxide. As for the nature of kieselgur and acid clay, the author preferred that the reply should come from a geologist.

To Mr. Miskin the author replied that the presence of silica would hardly explain the electronegativity of fuller's earth, since this property varies very widely, whereas the silica content does not vary to the same extent. With regard to the presence of carbon dioxide, he said that while the presence of lime could account for some of this, there was no doubt that the earths contained traces of organic matter, which would form carbon dioxide on heating.

The Author thanked Mr. E. H. Cunningham-Craig for his very interesting statements regarding the formation of fuller's earth in nature.

Replying to Messrs. Mendelssohn and Henson, the Author said that he was aware of the property of selective absorption of fuller's earth from a paper by Messrs. Gilpin and Bransky, published in the *Amer. Chem. Journal*, 1910, which gives an account of research carried out in order to prove the theory of the natural migration of oils.

To Mr. Peel the Author replied that the price of fuller's earth was relatively high—£4–£5 per ton. He pointed out that clays could be used provided they possessed the required bleaching power, but the method of using them is entirely different.

STUDENTS' SECTION, LONDON BRANCH.

The Seventh Ordinary Meeting of the Students' Section, London Branch, was held at Aldine House, Bedford Street, Strand, W.C.2, on Tuesday evening, May 27, 1924.

Mr. H. G. Austin (Hon. Sec.) before asking Mr. Garlick to take the Chair, stated that this was the final Meeting of the first Session of the Section. The Annual Report, which was published in Journal No. 42, had received the approval of the Council, who had sent a letter, congratulating the Section on its success.

Mr. H. S. Garlick then took the Chair, and called upon Mr. Austin to read his paper, an extract of which follows :—

Percussion Systems of Drilling.

By H. G. Austin.

Although no actual record of the earliest use of boring rigs is in existence, it is known that the Chinese drilled wells for brine before the time of the conquest of Britain by the Romans. An old document, published by the Jesuits in the 17th century, and still preserved in a museum at Amsterdam, describes the Chinese method of drilling by means of "an iron hand hung from the end of a cord."

The following is the description of the type of rig used for deep well drilling :—

A bamboo derrick in the form of a tripod was erected at the spot selected for drilling. Between the two front poles of the tripod two smooth logs of wood were fixed, one log near the top and the other about half-way up. A cable made from plaited Manila fibre was attached to the end of a hollow length of bamboo, the bailer. This bailer cable or "sand line," was led from the bailer over the top log of the derrick to the back of the rig, where it passed under a wheel and over a smooth piece of timber to a horizontal winding drum. A similar cable was attached to the top of the drilling bit, a thick flat piece of iron with the lower and sharpened to a chisel edge and weighing from 100 to 200 pounds.

The drilling cable was placed over the lower log of the derrick and brought down through a hole made in the end of a long spring-board, where it was knotted. The rest of the equipment consisted of a high platform placed immediately at the rear of the derrick and by the side of the spring-board. After a shallow hole had

been dug, and cased with timber to form a "conductor," the driller took his place by the side of the hole, whilst the rest of the crew—some five or six in number—took their turn in jumping off the platform on to the spring board, each jump causing the spring-board to jerk the drilling cable down sharply, and thus raise the bit. The coolie then jumped quickly off the spring-board, the bit fell freely to the bottom of the bore hole, and performed its duty of penetrating the formation. The driller himself, during actual drilling operations, twisted the drilling cable, so that the bit should drill a round hole.

As the bit drilled deeper, the free end of the spring board was pulled higher by the knot in the drilling cable, so that after each few feet of hole had been made, the drilling cable had to be untied and knotted again lower down. At the same time it was necessary to remove the drilling bit from the hole and clean out the detritus. The sand line was then thrown off the winding drum, to which the free end of the drilling line was attached, and a bull or ox trained for the purpose, was hitched to the drum and made to walk round it, thus winding the drilling line round the drum and raising the bit to the surface. The bailer was then lowered into the hole to remove the drill cuttings, after which the bit, which had in the meantime been "dressed" or resharpened, was run back into the bore hole and drilling continued. Hollow bamboo poles were used as casing, and were put into the hole length by length, as drilling continued. Although the rig and tools used may appear to be very crude, they were very efficient, and holes often reached a depth of 1000 feet in efforts to tap brine springs or water-bearing formations.

Very often, during drilling or bailing operations, the cable broke, and to recover the tools a "fishing string" was run—the particular fishing tool being selected to suit the lost tool.

For shallow boring, a very simple type of rig was used. Two of these rigs, which have been in use in many parts of the world for several hundred years, are the "spring pole" and "kicker" outfits.

Rigs similar in design and operation are still in use in America and England for shallow water well boring. The spring pole, about 30 ft. long, and tapering to one end, is secured and weighted down in a hole dug in the ground, and a fulcrum, placed at the point of balance, supports the pole at an angle of about 30 degrees, so that the tapered end is brought immediately over the spot selected for the well. Either drill rods or cable were used to connect the drilling bit to a swivel attached to the end of the spring pole. After the conductor had been dug and lined with boards, the cable or drill rods (whichever were used) were connected to the swivel and the bit was lowered into the hole. Crossed wooden handles were then clamped on to the drilling string at a

convenient height from the ground, and two men took hold of these handles, raising and lowering the bit, at the same time, turning it. The spring of the pole greatly obviated the work of lifting the bit and the length of stroke of the tools—that is, the distance the tools are raised at each oscillation of the spring pole—was frequently over two feet. A bailer was used to clean out the hole, which was cased either with hollowed logs or iron pipe.

The kicker method was a modification of the spring pole rig. A kicker board—a small platform of wood—was placed below and beyond the end of the spring pole. The back of the kicker board was hinged to a wooden frame raised off the ground, whilst the front of the board was connected to the end of the spring pole by a rope. A swivel formed the connexion between the spring pole and the drilling string, and motion was imparted to the tools by two men, who stood on the kicker board with their legs well apart, shifting their weight from one foot to the other, thus oscillating the spring pole.

About 1840 the brine well drillers of Virginia and Pennsylvania applied steam power to their drilling rigs, which were then very similar in design and operation to the old Chinese deep well outfit, described above. At first, the spring pole was discarded, and an engine and boiler were placed close behind the derrick. A long, oblong piece of timber was pivoted at its point of balance on a substantial wooden upright. The long piece of timber was known as the walking beam, and was erected between the engine and the borehole in such a manner that one end of it came directly over the end of the engine crankshaft and the other over the conductor of the borehole. The walking beam was connected to the crank-shaft of the engine by means of a crank handle placed on the end of the engine crank-shaft, this crank handle in turn being connected by a length of wood to the end of the walking beam. As the crank-shaft of the engine revolved, the walking beam was forced up and down on its pivot. The tools were connected to the borehole end of the beam, and thus the use of man power for the actual operation of drilling was dispensed with. The old type of winding drum was retained, however, and a rig such as this was used by Colonel Drake when drilling the first oil well at Titusville, Pa., 1855–59.

Drake, however, erected a wooden derrick, 34 ft. in height, with a square base, this derrick consisting of four "legs" of timber tapering upwards from the surface of the ground, these legs being braced and girted with wooden beams to add strength to the rig. At the top of the derrick a pulley was placed in the middle of a wooden table—the crown block—and the drilling cable was placed over this pulley, thus enabling the drilling tools to be easily pulled out of the hole, and stood ready in the derrick to resume their work

of making hole. The derrick also proved of greater assistance, by reason of its height, in the operation of setting casing, as several joints of casing could be made up ready for setting in the well and could be lowered altogether, instead of the casing having to be set one length at a time, as was the case with a short derrick.

The tools used by Drake were a drilling bit, an auger stem, a set of jars, and a rope socket. The auger stem was a round piece of iron, 5 ft. to 6 ft. long, used to add weight. The jars, which had been in use by the brine well drillers since 1832, were the invention of William Morris, and the introduction of this tool represented a great improvement in well drilling. They were formed of two links of iron, interlocked, so that the two links had a free stroke between them of several inches, and were placed above the auger stem and the drilling bit. On the down stroke the jars formed practically a solid part of the drilling string, and on the upstroke the top link was raised until it met the top of the lower link, thus causing a sharp jar, which was transmitted automatically to the drilling bit, releasing it should it have become stuck. The rope socket was a short piece of round iron, to which a ring was riveted, the drilling cable being attached to this ring. This was screwed on to the jars, and thus completed the string of tools, which weighed about 300 lb. in all.

It should be mentioned that 3-in. bits were used by Drake, the bits being made of iron, steel shod at the cutting edge. The tools were joined together by means of pin and box parallel joints, $1\frac{1}{2}$ ins. in diameter.

A temper screw formed the connection between the walking-beam and the drilling cable, and consisted of a threaded screw, $\frac{3}{4}$ in. in diameter, threaded into an iron frame. The screw was let down out of the framework by turning a cross bar, fitted near the bottom of the screw, and a pair of rope clamps hung from the end of the screw held the cable.

Rapid improvements in the application of steam power to drilling rigs were made, and a rig very similar in design to the present day Standard American Cable Tool Outfit was gradually evolved and was in general use throughout the oilfields of the United States by about 1885.

The following description of the 1885 rig will also serve to illustrate in many details the modern standard rig :—

After wooden foundations and sills had been placed on the well site, a wooden derrick 50 ft. to 60 ft. high was built and fitted with a crown block, similar to that used on the Drake well. The engine and boiler used were of the type in which the engine is placed on top of the boiler, and was placed in a shed built about 40 ft. away from the derrick. The engine house was connected to the derrick

floor by means of a walk partly covered in to form a protection to the transmitting gear. Halfway along this walk was built a large wheel, about 7 ft. in diameter and 10 ins. thick, supported on a strong shaft. A belt was placed round the band wheel, connecting it to the pulley of the engine, which, it should be mentioned, was of the single-cylinder type. On one end of the band wheel shaft a crank handle, fitted with a wrist pin, was placed, and this crank handle was connected to a walking beam. On to the other side of the bandwheel a grooved wheel, known as the tug rim, was nailed concentrically. On the side of the derrick opposite to the walking beam a shaft fitted with a large wheel at each end was built up. One wheel of this bull wheel, as it was named, was in line with the tug rim of the band wheel, from which it was driven by a thick "bull" rope. The drilling cable was spooled on to the bull wheel, carried over the crown pulley, and then brought down and attached to the rope socket.

At the rear of the band-wheel a small reel, fitted with a wheel having a wide face, was constructed on a movable frame. On to this reel the sand line, or bailing line, was spooled, using the engine for this purpose, the wheel of the sand reel being brought into frictional contact with the face of the band wheel. The end of the sand line was then carried up and placed over a pulley hung just below the crown block, thence down into the derrick ready to be attached to the bailer.

From the above it will be seen that the band wheel transmitted motion in three different directions: (1) for drilling through the walking-beam; (2) for raising the drilling string out of the hole and for handling casing through the bull-wheel; and (3) for cleaning out the hole, or bailing, through the sand reel.

The drilling string was composed of a bit, auger stem, jars, sinker bar and rope socket. Larger size bits had been introduced, ranging up to 10 ins., and the amount of steel used for the cutting edge of the bits was as follows:—For the 3-in. bits, 20 to 30 lb.; for 6-in., 60 to 80 lb.; for 8-in., 80 to 100 lb.; and for 10-in., from 100 to 120 lb.

Below the collars of each tool two square surfaces were cut, to which wrenches were applied when making and breaking the joints.

When the complete drilling string had been made up it was lowered into the hole, the drilling cable was attached to the rope clamps of the temper screw, and the engine was set in motion, thus oscillating the walking beam, which raised and let fall the tools, the temper screw being let out as work proceeded to allow the cable to be kept taut when the bit was on the bottom, thus insuring that the tools were kept upright in the hole for the drilling of a perfectly

straight hole. After each run of the temper screw the drilling cable was taken out of the rope clamps, the walking beam disconnected, and the tools withdrawn from the hole. The sand pump or bailer was then lowered into the hole to clean out the detritus. The drilling tools were then connected up again, and drilling continued.

It was frequently necessary to change the bit, owing to the blunting of the cutting edge, and at least two bits of each size were included in each outfit, so that whilst one was in use the other could be resharpened or "dressed" by the tool dresser.

The cables used for drilling and for bailing were made of manila fibre, the drilling cable being from 2 in. to 2½ in. in diameter, the sand line from ⅞ in. to 1 in. in diameter, and the bull ropes being from 2½ in. to 3 in. diameter.

Two different types of rope sockets were used, the ring socket and another into which the cable was clamped and riveted. The boxes and pins also had parallel joints similar to those used by Drake, but the joints themselves were shorter and larger than those fitted to the early tools.

About the year 1880, Jonah Smith, a Pennsylvanian driller, used drilling tools fitted with taper joints, these permitting of "draw." This type of joint was infinitely superior to the old parellel joint, which, after frequent use became worn, resulting in the joints being loose and uncertain. The taper joints, however, did not come into general use throughout the American oilfields until many years after their introduction by Smith, but they are now regarded as standard.

In 1892, a wire rope of ⅝ in. diameter was introduced as the sand-line, in place of the manila line, and this necessitated the use of iron sand reels. Wire lines for drilling have now come into general use, although many drillers still prefer to use manila cable, or else a wire line spliced on to a length of manila cable, which is used immediately above the drilling tools. As a general rule, manila cables are used when drilling in a dry hole, and wire lines in holes which are wet, owing to penetrated water bearing strata, and in soft or shale formations.

When a well was commenced, the first hundred or so feet were spudded, that is, a large size bit was used with only an auger stem until a sufficient depth was reached for a complete string of tools to be operated from the walking-beam. The spudding bit and stem were placed in the hole and a jerk line was connected at one end by a loop to the wrist pin of the crank, the other end being attached to a ring which ran on the drilling cable (between the bull wheel shaft and the crown block). As the crank revolved, the jerk line pulled the drilling cable towards the mouth of the

bore-hole, thus raising the tools in the well and dropping them again.

Pipe is often "driven," and this is accomplished by placing a specially hardened shoe on the lower end of the pipe round forging, and on the top joint a hollow forging, through which the tools are lowered. A set of drive-clamps are placed on the wrench square of the pin end of the stem, so that when the tools are raised and lowered by the walking beam, the drive clamps hit the top of the drive-head on the pipe, forcing the pipe downwards. The core of rock inside the drive-pipe is removed by the drilling string being operated in the usual drilling operation, to loosen the core, and the bailer cleaning out the pipe.

In addition to the bailer, a sand pump was frequently used to clean out thin mud or sand in the hole. This implement is similar to the bailer, but with a sucker valve and plunger instead of the bailer's dart valve.

The operation of drilling has not changed since the outfit described above was evolved, and the chief difference in this outfit and the standard cable tool outfits used to-day is that the latter are proportionately larger. A larger variety of drilling and fishing tools is employed, and frequently steel derricks are used.

In the old rigs, the rig irons used were usually not larger than $3\frac{1}{2}$ in.—this dimension being the diameter of the band wheel shaft. The modern cable tool rigs employ rig irons from 4 in. to $7\frac{1}{2}$ in., according to the depth to which it is intended to drill.

Drilling bits from 30 in. down to 3 in. are now manufactured, and auger stems, jars, sinker bars and rope sockets are large in proportion, compared with similar tools used in the early days.

The boxes and pins to join the tools now range in size from $1\frac{1}{8}$ in. by $1\frac{3}{4}$ in. to $4\frac{1}{4}$ in. by 6 in., these measurements being the diameters of the pin at its tapered end and at its junction with the collar of the tool respectively. All boxes and pins are threaded with either sharp (V) or flat threads, eight or seven to the inch. The eight sharp threads to the inch joint is used on tools fitted with joints $1\frac{3}{4}$ in. by $2\frac{3}{4}$ in. and smaller, and the seven threads flat are placed on the larger joints, from 2 in. by 3 in. upwards. The size of wrench square varies in proportion to the size of the box and pin. The term "joint" when used in connexion with cable tools covers one complete join in the tools, consisting of the box end wrench square, the box collar, the threaded box itself, the threaded pin, the pin collar and the wrench square of the pin collar.

To make and break the tool joints, a rack bent in the form of an arc, and having parallel teeth, is placed on the derrick floor near the mouth of the borehole. A small "cage" travels along the rack, moving when the pawl mechanism is operated by a long

wooden handle, the cage travelling one tooth or notch at every stroke of the handle. Two tool wrenches are placed one on each of the collars of the tools being joined, the end of one wrench being fixed against one end of the rack, and the end of the other being placed on the cage, which, travelling along the rack, brings the tool wrenches together, thus effecting a tight joint.

The height of the derrick is governed by the depth to which it is intended to drill, the usual Standard derrick for a 3000 ft. hole being 72 ft. high, with a 20 ft. square base, 4 in. or 4½ in. rig irons being used. For a 4000 ft. well, an 82 or 84 ft. derrick, with 20 ft. base and 6 in. rig irons is employed, although it must be understood that the actual height of the derrick and the length of one side of the base and size of rig irons varies frequently, according to the locality, and depth of hole to be drilled.

To handle and set casing, a casing outfit is employed, this outfit consisting of a spider and slips, and sets of elevators to suit the sizes of casing used. The spider is a forged piece of iron with a circular hole large enough to allow the largest size of casing used to pass through it with a good clearance. The starter or lowest joint of casing is equipped with a casing shoe, to protect the threads of the casing and to form a strong ring to work into the formation in which the casing is set. A joint of casing is usually from 18 to 20 ft. long, so that several lengths may be screwed together in the derrick, according to the height of the derrick; for instance, three joints can be easily handled in an 82- or 84-ft. derrick. The spider is placed over the borehole, and the first lengths of casing are passed through it and held in it by slips—tapering pieces of steel with serrations to afford a better grip on the pipe. The next string of casing is then supported in the derrick by means of an elevator—a round ring, equipped with a gate that can be opened or shut, and hung on either one link or two links, which in turn are suspended from a casing hook which is attached to the end of the drilling line. This second string is brought over the top of the first string in the spider and screwed into it, after which the slips are removed, the second string lowered into the hole until the elevator approaches the spider, when the slips are again put in the spider to grip the pipe, and the elevator is thrown off and raised into the derrick again to support the next string of casing.

In difficult territory it is frequently necessary to "underream" the hole to make a good clearance for the casing to be set. This operation is effected by using a suitable size underreamer—a long solid piece of steel in the shape of a short stem, in the bottom of which are fixed two cutters. This underreamer is lowered into the hole at the bottom of the regular string of tools in place of the drilling bit, and the walking-beam is used to give the same motion

as is applied to drilling, the cutters of the underreamer cutting away the formation to allow the casing to be set easily.

In California it was found that the formations caved too quickly to allow the setting of casing easily, so that a calf wheel rig was employed. This rig was the ordinary cable tool rig fitted with a wheel, the calf wheel, between the walking beam and the derrick leg, driven from a sprocket on the band wheel. A casing line was spooled on to the calf wheel shaft, and passed alternately over the casing pulleys in the crown block, and through the sheaves in a travelling block, to which was attached a casing hook connecting to the elevators. In certain fields of California, however, the formation was so loose that before casing could be set with the calf wheel the hole had caved in. To overcome this difficulty a swinging spider was invented. This swinging spider was really an elevator with very long reins, which enabled drilling to be carried on whilst the casing was suspended and kept moving in the hole.

For drilling up to about 3000 ft. and for prospecting portable machines are frequently used. These machines carry all the equipment, together with the engine, in one frame, easily transported from place to place. In the smaller types of portable machines the boiler, which is of the vertical type, is also mounted on the frame, and a mast fitted to the outfit is used as a derrick.

Regarding the power used for the Standard System, the size of engine and boiler depends on the depth of well, a 12-in. by 12-in. single cylinder engine and a 45-h.p. locomotive type boiler being sufficient when drilling to a depth of 3000–3500 ft. Steam power is in general use throughout the oilfields to-day, as it is simple in generation and is flexible. Internal-combustion engines have been put on the market for use in drilling, but except for countries where water is scarce there is little demand for such engines. Electricity, where available, is rapidly being adopted for use in deep well drilling, a three-phase, 75-h.p. 60-cycle induction type motor being found satisfactory for general drilling work.

It should be mentioned that the usual type of boiler used in the oilfields is the portable locomotive type, although, of course, the boiler regulations of each country have to be adhered to when drilling for oil in that country.

The Canadian Galician outfit, used in the oilfields of Galicia and neighbouring countries, consists of a compact wooden framework, with one main shaft and two reels for transmitting power. Instead of a temper screw a slipper-out is used on the end of the walking beam, giving the "feed" to the drill poles, which are used in place of the drilling cable.

The Russian freefall system is compact, the three wheels for the transmission of power for drilling, bailing, and for setting casing being in one frame, very similar in lay out to the Canadian Galician

rig. A walking-beam and temper screw are used, the action of the tools being as follows :—The rods, with the tools, consisting of a bit, under-reamer, sinker bar and free fall mechanism, are lowered into the hole, and adjusted to allow the bit to just touch the bottom. The down stroke of the walking-beam causes a spindle inside the free fall to engage on a projection on which this spindle is allowed to rest on the up-stroke. By rotating the drilling string at the temper screw the spindle with the bit and under-reamer is released and falls freely to the bottom of the hole, a drop of about 4 ft. The free fall mechanism again engages the spindle on the upward stroke, and the operation is repeated.

Casing.—Casing used when drilling with the various percussion rigs varies in standards, according to the locality. In the majority of the American oilfields collared casing is used, the standard sizes for an average well being 15½ ins., 12½ ins., 10 ins., 8¼ ins., and 6¼ ins., a short string of 18-in. drive pipe being used as the conductor. Casing is usually threaded with ten threads per inch, and the two joints do not meet inside the coupling. Drive pipe, however, which is usually employed for the larger sizes only, is generally threaded eight threads per inch, and the two joints butt in the coupling, thus giving great strength to the pipe when driving it. Inserted joint casing is also used in many fields outside the United States, while riveted casing is principally used in Russia, although some fields of the U.S. employ riveted casing for the conductor.

Several other percussion systems other than described above, such as the Fauck-rapid, the Raky, etc., are all developments of one of the three main systems, and their method of operation is very slightly different, the chief variation being the use of a water-circulating system in conjunction with the ordinary string of cable tools.

In conclusion, it must be stated that there are many details of the percussion system which it has been impossible to include in this paper, but it is hoped that the paper will have given the student who has not studied drilling, or whose profession does not bring him into contact with the actual production side of the oil industry, a knowledge of the percussion system.

Mr. Garlick thanked the author for a very interesting paper, which, with the slides shown, had given the members present a remarkable collection of detail regarding the evolution of the percussion system.

Mr. A. B. MISKIN complimented the author on the masterly way in which he had handled his subject. He asked whether a twin-cylinder steam engine would not be better than a single-cylinder engine, especially when setting casing. When drilling on a rotary rig he found that a single-cylinder engine frequently

stopped on centre, requiring much effort to restart the engine. Mr. Miskin also asked whether steel rigs were not very dangerous when drilling in areas affected by lightning storms. He did not quite understand the function of the four-way or star bit, and requested information as to the relative life of the manila cable as compared with the wire line. As a geologist, he was able to appreciate the use of a cable tool rig when drilling a "wild cat," as accurate samples of the formations penetrated could be secured—the rotary rig, although making hole faster, did not give the driller any assistance with regard to samples of the strata, unless core barrels were used. Mr. Miskin also enquired whether a "Uniflow" engine had been tried on an oil well.

Mr. C. C. Wilson did not quite understand the different uses of the bailer and the sand pump.

Mr. T. G. B. Davies asked how many men were employed on a rig.

Mr. A. C. Mendlesohn enquired as to the difference in the duties of the driller and the tool dresser.

Mr. Austin, in reply to Mr. Miskin, said that whilst twin engines had proved of great advantage in rotary drilling, the absence of flywheel momentum facilitating quick starting and stopping, a slower motion was obtained with the twin engine, this being of advantage when making up casing. The twin engine also cannot stop on centre. The single-cylinder engine, however, was the best type to use on the cable rig, as the momentum of the flywheel imparts a strong steady motion to the tools, especially when drilling at great depths. As regards the risk of lightning when drilling with steel rigs, it was pointed out that the rig acts as a conductor, and that wooden derricks were really just as liable to be struck as were steel derricks. Mr. Austin endorsed Mr. Miskin's remarks in respect to the cable tool rig when wild catting—the cable tools were the safest method of securing accurate formation samples. Regarding the Uniflow engine, he was unable to give any particulars of its use in the oilfields.

In reply to Mr. Wilson, it was explained that the sand pump was used to take sand and thin slush out of the well, as this would not enter the bailer readily. The suction caused by the plunger of the sand pump drew the sand into the body of the pump, where it was trapped by a clack valve.

Mr. Austin, in reply to Mr. Davies, said that the usual crew of the cable tool rig consisted of the driller, the tool dresser, and a roughneck, whose duty it was to fire the boiler and to act as elevator man when setting casing. In deep-well rigs, when setting casing, as many as five men altogether were employed.

In regard to Mr. Mendlesohn's question, it was explained that

the driller himself, during actual drilling operations, usually kept his hand on the drilling cable, below the rope clamps, as after a few years of experience, it was possible to tell what type of formation was being penetrated by the "feel" of the rope. The tool dresser operated the brakes of the bull wheel, and, of course, dressed the drilling bits, which in itself was an art only learnt after good experience. It was very easy, indeed, to crack or break a wing off a bit by careless or inexperienced dressing. The driller and tool dresser frequently shared the duties of the rig, and it was explained that a man graduated from the position of roughneck, or handyman, to a tool dresser, and from a tool dresser he became a driller, having actual charge of the complete outfit.

Mr. Garlick in thanking the author for his explanations, expressed the hope that someone would come forward to take up the post of honorary secretary. He was confident that the Section would continue to grow in numbers and in usefulness to the oil industry. He wished to pass a hearty vote of thanks to Mr. Austin, who, as Chairman and Honorary Secretary, had organised the Section, and had been responsible in a large measure for the success of the Section.

Mr. Miskin, in seconding the proposal, on behalf of the Section, wished Mr. Austin every success in his career. The proposal was passed unanimously.

In reply, Mr. Austin thanked the members for their kindness and good wishes, and stated that it was the co-operation and support of the members, especially those on the Committee, which had contributed to the ultimate success of the Section.

An Addition to the Mineral Resources of Western Canada: Bentonite or Colloidal Clay.*

By Hugh S. Spence.

Attention has been directed during the last few years to a peculiar clay found in the western parts of the United States and Canada, called bentonite. The clay was first described from the State of Wyoming, and has been found also in other States of the Union, and in the Provinces of Manitoba, Saskatchewan, Alberta and British Columbia, in Canada. The Mines Branch of the Department of Mines of Canada has recently made a survey of the known bentonite deposits with a view to determining the extent to which the clay occurs in Canada.

It has been found that bentonite is pretty widely distributed in the upper sections of the Cretaceous rocks which cover the greater part of the Prairie Provinces, and that many of the sandy or shaly beds in this series of rocks are bentonite in varying degree. The sticky "gumbo" soils of the west owe their character to the presence in them of bentonite, which swells up when wet and forms a pasty mass that makes the prairie roads at wet seasons almost impassable. The University of Alberta is at the present time conducting experimental work in the improvement of highways by counteracting the evil effects of bentonite.

The bentonite beds of the Canadian West range in thickness from a few inches to as much as 14 feet. The latter thickness is exceptional, but several deposits measuring 6 to 8 feet are known. The deposits which probably offer the best possibilities for immediate development occur in southern Saskatchewan and southern British Columbia, where beds are found quite close to railway transportation. No production from any of the deposits has yet been made, owing to the lack of a market. In the United States, however, two companies are now marketing bentonite; one of these produces only crude clay, and the other both crude and powdered material. These companies report that the market is small as yet, but is growing steadily each year, and that an encouraging interest is being manifested in the possibilities of the clay by the most varied industries. In 1921 the Mines Branch arranged the shipment of five tons of Alberta bentonite to the Imperial Mineral Resources Bureau, 2, Queen Anne's Gate

* Received by the High Commissioner for Canada in London from the Dominion Department of Mines, Ottawa.

Buildings, London, for research purposes and for distribution in British industries. It is understood that the Bureau still has a quantity of the clay on hand.

Bentonite in the dry state looks much like any other clay. It is only when it is wetted that its peculiar physical properties become apparent. The name bentonite was given about 25 years ago to the clay from a bed that occurs in rocks of Upper Cretaceous age (Fort Benton series) in Wyoming, and attention was drawn to the material on account of its excessively sticky nature and its high water absorption. It possessed, in short, the physical attributes of what are now called "colloids." Briefly, bentonite is a clay substance, the individual particles of which are so small that they are invisible even under the highest powered microscope: they are not crystalline like ordinary clay particles, and when mixed with an excess of water form what are called "hydro-sols"—that is, permanent suspensions, or dispersions, from which the clay will not settle out, even if allowed to stand indefinitely. By virtue of the relatively enormous surface presented by the particles, bentonite possesses great absorptive power, and the dry clay will absorb many times its volume of water, swelling up to a sticky, jelly-like mass. The particles have the property of absorbing chemical compounds also, such as salts, dyes, etc., out of solution, and of effecting base exchange between salts of the alkali and alkali earth groups.

These properties have suggested a very wide field of usefulness for bentonite in industry. Some of the more important of these uses are: as an absorbent of dyes and colours; to increase the strength of cements and plasters; as a suspending agent for enamels and glazes in the metal enamelling and ceramic industries; as a bonding agent in crucible bodies, electrical and chemical porcelain and abrasive wheels; as a de-watering agent for petroleum, gasoline and oils generally, as well as for air and gases; as a mordant and as a base for lake colours in the dye and colour industry; as an accelerator and stabiliser of emulsions of various types, and in the preparation of asphalt, coal tar residues and pitch emulsions; as an absorbent of nitro-glycerine in the manufacture of dynamite; as a filler material for fertilisers; and for paints, rubber and moulded composition products of various kinds; as a suspending agent in core washes for foundry work, and as a bonding agent in moulding sands; as a sticking or spreading agent in insecticidal sprays and dusts, and to increase the wetting power of cattle dips; as an ingredient of lubricants; in cold water paints or distempers; as an ingredient of adhesive pastes; as a sizing agent for textiles, cordage, etc.; as an ingredient of crayons, indelible pencil leads and pastel colours, and of printers' inks; for increasing the retention of china clay

in the manufacture of paper and for removing the carbon black particles in the de-inking of newsprint; to remove the impurities from petroleum, gasoline and lubricating oils, as well as from packing-house products and vegetable oils (acid-treated clay); to replace whiting in putty; as a source of pure colloidal silica, or silica gel; as a detergent in soaps and scouring compounds; as an ingredient in stove polish; in pharmaceutical products, cosmetics, facial clays, etc.

The above list by no means exhausts the many suggested uses for bentonite. Thus far, important commercial utilisation has been confined to the paper and oil industries, the latter being by far the largest consumer. The clay in this case, while probably more or less identical with bentonite, is variously termed halloysite or otalite, and is found in southern California; large quantities have been used by the Pacific Coast oil refineries, the clay being first treated with acid.

Bituminous Sands of Northern Alberta.*

By S. C. ELLS.

Mining Engineer, Mines Branch, Ottawa.

WORK undertaken by the Mines Branch, Department of Mines, has included topographic surveys of extensive areas, examination and sampling of the principal outcrops, the mining of trail shipments, laying of demonstration pavements, and a study of methods adapted to the recovery of bitumen from the crude bituminous sand.

GENERAL DESCRIPTION OF AREA UNDERLAID BY BITUMINOUS SAND.

The Athabaska and Clearwater valleys constitute the chief topographic features of the area under discussion.

On leaving the valleys, elevations gradually increase. Toward the east, large areas of country are covered by sand derived from the disintegration of pre-Cambrian rocks. In passing westward, the sand gradually disappears and clay soil predominates.

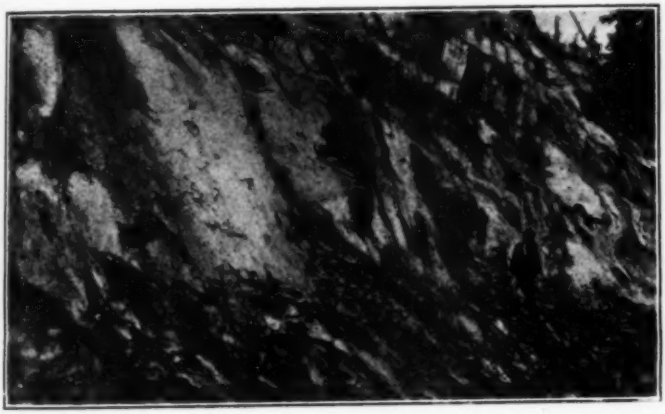
GENERAL DESCRIPTION OF DEPOSITS.

(*a*) *Extent of Deposits.*—It appears unnecessary—nor is it indeed at present possible—to attempt an accurate estimate of the area underlain by bituminous sand.† The writer has examined upwards of 270 individual outcrops, all of which represent portions of a more or less continuous deposit. These outcrops extend along the Athabaska river and its principal tributaries, through a total distance of more than 220 miles. The direct distance in a north and south direction through which outcrops have been noted is approximately 35 miles. Extensions of the deposit under heavy overburden, particularly toward the south, will materially increase the above estimate. Having due regard to methods at present practicable for mining bituminous sand, and considering other controlling factors such as variation in quality, the area actually

* Abstract from article reprinted from *Canadian Mining Journal*, March 28 and April 5, 1924, and received from the Office of the High Commissioner for Canada in London. See also this JOURNAL, vol. 10, No. 43, p. 358–359.

† For approximate calculations, it may be assumed that one ton of mixed materials is equivalent to 14·5 cubic feet, or 9·5 square yards of 2 inch compacted sheet asphalt wearing surface.

OUTCROP OF BITUMINOUS SAND, ATHABASKA RIVER, ALBERTA.



OUTCROPS OF MASSIVE, HIGH-GRADE BITUMINOUS SAND, STEEPBANK RIVER, ALBERTA.

OUTCROP OF MASSIVE, HIGH-GRADE BITUMINOUS SAND, STEEPBANK RIVER.

available for commercial development at present probably does not exceed one per cent. of the above estimate.

In view of the above it will be seen that, in considering possible commercial development of bituminous sand areas, the thickness of overburden and the ground available for the disposal thereof, freedom from impure partings, uniformity and degree of enrichment, and conditions affecting transportation, may be recognised as among the principal controlling physical factors.

Variation in Bituminous Content.—To some extent the degree of impregnation has depended on the grade of the sand. The medium grained and moderately compact deposit is usually the richest, whereas the finest aggregates, although possessing a larger volume of voids, have retarded complete saturation. Thus the percentage of associated bitumen varies widely in all exposed sections examined.

Impure Partings.—In the study of petroleum fields, an appreciation of the probable genesis of petroleum is obviously of practical importance. No less important is a study of conditions that have resulted in the formation of the Alberta deposits, and of the origin of the associated bitumen. This feature will be more fully discussed in a complete report now in course of preparation.

For many years the occurrence of so called "tar (springs") or seepages of bitumen has been recognised throughout the area under discussion. The writer is familiar with upwards of 40 such springs, but in no instance are they in themselves of commercial value as a source of bitumen. They have, at times been regarded erroneously as a definite indication of the presence of petroleum pools. Instead of coming from below, however, the bitumen merely seeps laterally from slightly inclined beds of particularly rich, coarse grained sand. An underlying impervious clay parting, together with a small local depression, makes possible the formation of a small pool of bitumen.

It is noticeable that in general the lower portions of the deposit consist of unstratified sands, and prior to impregnation these sands were apparently uncompacted. Consequently, these lower portions are usually of a fairly homogeneous character. In passing upward, however, narrow bands of sandstone, clay, lignite, and occasional quartzite are found interbedded. These unimpregnated strata gradually increase in number until, by their preponderance, they may at times almost entirely replace the bituminous sand.

(c) *Thickness and Character of Overburden.*—In the Athabaska valley and along the principal tributary streams areas may be subdivided into two general groups:—

(i) Low lying areas represented by outcrops that rise to a height of 5 to 30 ft. immediately along the present stream channel. These

outcrops represent such small residual areas of bituminous sand as still remain in the original valley bottom, and have a comparatively light overburden.

(ii) Exposures where streams have impinged against the sides of the main valley. Such exposures, in general, show a thick section of bituminous sand and also a heavy overburden. Topographic maps in preparation illustrate those areas where overburden is either very heavy or comparatively light. Such maps, however, must eventually be supplemented by systematic core drilling.

As might be expected in a country covered by a heavy mantle of clay in which streams are deeply entrenched, slips in the bank constitute a notable feature. Individual slides at times bring down many thousands of tons of clay and soil.

In passing northward, elevations and consequently depths of overburden throughout the zone drained by the Athabaska river gradually decrease.

A brief reference to the geologic section along the Athabaska river will furnish some indication of the general character of the overburden. Between Athabaska and the Cascade rapids, La Biche shales, Pelican sandstones and shales, Grand Rapids sandstones and Clearwater shales are, at various points, well exposed; but northward and eastward from the Cascades rapids the Clearwater series and surface drift appear to constitute the entire overburden above the bituminous sand. Thus, in undertaking stripping operations, the class of material to be excavated should present no serious difficulty, since shales and soft sandstones, with occasional thin bedded quartzites, apparently represent the bulk of the strata to be removed. The surface drift consists chiefly of boulder clays and sand. Obviously, other things being equal, areas lying within triangles at the junction of two streams present material advantages from the standpoint of the removal and disposal of overburden.

Prospecting.

The method adopted in prospecting any bituminous sand area will depend on the thickness and character of the material overlying the bituminous sand, and on the accessibility of the area by water or pack trail transportation. Where the thickness of overburden does not exceed 30 ft., test pits may be sunk economically to the bituminous sand, and core samples then secured by means of asphalt augers. Where the overburden exceeds 30 ft. in thickness, core drilling by means of light power drills will be found more efficient. Trenching above outcropping bituminous sand rarely gives satisfactory information as regards the thickness and character of the overburden.

Characteristics of Sand.

The sand consists, for the most part, of clear quartz grains. In form the grains are most irregular, varying from sharply angular to oval, water-worn shapes. Judging from the grading of the sand, the bulk of which ranges from 40 to 80 mesh, the greater part may be considered as originating as shore deposits.

The following is an analysis of sand combined from samples taken from six representative outcrops :—

	Per cent.
SiO_2	95·50
Al_2O_3	2·25
CaO	0·50
Fe_2O_3	0·35
MgO	0·23
Loss on ignition	1·50
Total	100·33

The physical characteristics of a representative sample of the bituminous sand and of the bitumen itself may be briefly summarized thus :—

*Crude bituminous sand.**

Specific gravity 25° C./25° C.	1·75
Moisture	1·3%
Bitumen soluble in CS_2	18·5%
Sand	80·2%

Extracted bitumen.†

Specific gravity, 25° C./25° C.	1·018
Fixed carbon	7·23%
Sulphur	4·85%
Bitumen soluble in 76° naphtha	82·8%
Bitumen soluble in 88° naphtha	78·2%
Carbenes	trace

* The following table indicates the tonnage of bituminous sand for various areas and thickness. Specific gravity of bituminous sand taken as 1·75. Short tons of 2,000 lbs.

Thickness in feet.	Tons on 1 acre.	Tons on 2 acres.	Tons on 3 acres.	Tons on 4 acres.	Tons on 5 acres.
1	2,380	4,800	7,100	9,500	11,900
5	11,900	23,800	35,000	47,700	59,600
10	23,800	47,700	71,600	95,400	119,200
15	35,800	71,600	107,300	143,100	178,905
20	47,700	95,400	143,100	190,800	238,500
25	59,600	119,300	178,900	238,500	298,200
30	71,600	143,100	214,600	286,200	357,700
35	83,500	166,900	250,400	333,900	417,400
40	95,400	190,800	286,200	381,600	477,000
45	107,300	214,600	321,900	429,300	536,600
50	119,200	238,500	357,700	477,000	596,300

† All extractions by use of CS_2.

Ash*	trace
Saturated compounds in 88° naphtha solution	39·6%
Unsaturated compounds in 88° naphtha solution	60·4%
Stickiness	4881·0%
Penetration at 115° F.	Too soft
Penetration at 77° F. (100 grams. 5 secs.)	Too soft
Penetration at 77° F. (100 grams. 1 sec.)	9·0 mm.
Penetration at 32° F. (100 grams. 5 sec.)	2·5 mm.
Ductility at 77° F.	100 cm.+
Volatile 160° C.—5 hrs. (Using New York testing oven)	11·2%
Volatile 205° C.—5 hrs. (Using New York testing oven)	14·2%
Volatile 250° C.—4 hrs. (Using New York testing oven)	18·8%

Characteristics of residual bitumen after heating	5 hrs. 165° C.	5 hrs. 205° C.	4 hrs. 250° C.
Specific gravity, 25° C./25° C.	1·021	10·77%	1·028
Fixed carbon	8·99%	None	12·33%
Sulphur	None	Trace	None
Carbenes	Trace	144° F.	Trace
Fusing temperature	106° F.	too soft	125° F.
Penetration at 115° F.	too soft	1·025	too soft
Penetration at 77° F. (100 grams. 5 sec.)	26·2 mm.	12·2 mm.	5·8 mm.
Penetration at 32° F. (200 grains 1 minute)	10·5 mm.	5·3 mm.	2·4 mm.
Ductility at 115° F.	100 cm.+	100 cm.+	34·5 cm.
Ductility at 77° F.	100 cm.+	99 cm.+	45·0 cm.
Tensile strength at 115° F.	—	—	0·3 Kgs.
Tensile strength at 77° F.	—	—	1·5 Kgs.
Tensile strength at 32° F.	—	—	25·5 Kgs.

Paving Construction.

Following a preliminary examination of the deposits of bituminous sand undertaken in 1913, the writer suggested that a section of experimental pavement be laid. It was felt that such a pavement would illustrate in a practical manner the value that should attach to the Alberta deposits as a possible source of a suitable paving material. During 1914, therefore, a quantity of the bituminous sand was mined and shipped to Edmonton, where it was laid as a pavement. This pavement comprised sections of three types of surfacing, viz., sheet asphalt, bitulithic, and bituminous concrete, and was opened to traffic on August 26, 1915. In October, 1923, the pavement was still in first-class condition, and up to that time had required no repairs.

As a site for this pavement, a section of Kinnaird street immediately south of Alberta avenue, Edmonton, was selected. The traffic along this part of Kinnaird street may be classed as heavy,

* Fine mineral matter not removed by extraction.

and the pavement has, therefore been given a fairly severe test. Apart from a considerable volume of fast automobile travel, traffic includes vehicles that carry loads up to eight and ten tons.

The principal arguments advanced against the use of crude bituminous sands as a paving material are :—

(*a*) Unbalanced mineral aggregate.
(*b*) Lack of uniformity.
(*c*) Freight charges.

In the past consideration of the merits of bituminous sand has been based largely on the assumption that mixes in which it may be incorporated must conform to present recognised standard paving specifications. In the opinion of the writer an attempt should be made rather to design a mix in which the admittedly valuable inherent merits of the material will be utilized to the greatest advantage. At present it is not definitely known whether a large tonnage of uniformly graded bituminous sand is available, but in the writer's opinion, areas can be found where such conditions exist.

United States Experience.

In certain parts of the United States, bituminous sands and sandstones and bituminous limestones have been used to some extent as a surfacing material for city streets and country highways, viz., in California, Oklahoma, Texas, and Kentucky.

Recovery of Hydrocarbons.

In 1913, the writer indicated that, in any attempt to ship crude bituminous sand, freight charges would handicap seriously any large commercial development in the McMurray district.

Market for Bitumen.

At present it appears that the market for solid or semi-solid bituminous in Western Canada is limited.

Asphalt, Solid.

	1911–12	1912–13	1913–14	1921–22	1922–23
Value $ ..	139,586	276,431	127,446	64,506	72,197
Tons	7,857	17,814	7,363	—	3,367

Asphalt, Not Solid.

	1913–14	1921–22	1922–23
Value $ ..	24,412	339	11,336

This market should be susceptible to material expansion, when various applications for what is admittedly a high-grade bitumen

become more widely recognised. Among such applications already recognised and to some extent demonstrated, are its use as asphalt cement in the construction of city streets, highways, and sidewalks; as a binder for briquetting fuels; as a base for paints and varnishes; as an ingredient of roofing preparations; and as a constituent of synthetic mastic, which has a wide application in connection with building construction. Among the many uses to which mastic has been successfully applied are the construction of various types of flooring (as in public buildings, breweries, courtyards, laboratories, armouries, powder magazines and explosives factories, railway and freight sheds), footways, roofing, damp courses, foundations for high-speed machinery, engine beds, and heavy hammers, waterproofing courses for arches of bridges and viaducts, fireproofing, lining of acid proof tanks, and compressed slabs or blocks.

Production of Petroleum.

The production of crude petroleum* or petroleum fractions from bituminous sand is a many sided question which can merely be touched upon in a brief paper such as this. The importance of such a production, if commercially feasible, requires no emphasis. Petroleum has become a fundamental necessity in the industrial and military life of a nation. Fuel oil is necessary for a navy, a mercantile marine and for large industrial plants. Lubricating oil is essential for all machinery.

At present Canada depends largely on the United States for her supplies of petroleum products. Yet in the United States, with a production of crude petroleum during 1923 of 725,702,000 barrels, the public, the Government, and the oil companies already appreciate the gravity of the situation that will result when the domestic supply becomes so depleted as to fail to meet demands. Those that look beyond periods of temporary over-production realise that the problem of furnishing sufficient oil to meet the inevitable and rapidly increasing demands is indeed of prime importance.

It is evident that the production of petroleum from Alberta bituminous sands is a question that should be given careful consideration. Such a production would apparently be relatively free from certain well recognised hazards that attach to the present production of well petroleum. Among these may be mentioned

* Total quantities and value of petroleum products other than solid and semi-solid asphalts entered for consumption in the provinces of Manitoba, Saskatchewan, Alberta and British Columbia.

1921–22		1922–23	
Gals.	Value	Gals.	Value
168,057,671	$13,111,167	167,705,479	$11,998,088

the uncertainty of locating oil pools, the uncertainty respecting amortization, the fluctuating price hazard due largely to uncertainty of uniform production, and the danger of new discoveries more advantageously situated with respect to markets.

In a short paper it is impossible to mention the many and various attempts that have been made to recover the hydrocarbon content from bituminous sand. The writer's investigation has included a determination of the relative efficiency of chemical solvents, and of various petroleum distillates; separation of bitumen by heated water at temperatures up to 320° F.; separation by flotation methods and final purification of partially refined bitumen, by means of filter presses and centrifuging. The possible use of crude bituminous sand as fuel has also been considered, and the value of spent sand as a basis for the manufacture of glass. Distillation of the crude bituminous sand has been attempted. The crude petroleum recovered in this manner has been fractioned and the various fractions refined by the use of sulphuric acid and aluminium chloride. The results of this work are inconclusive.

DISCUSSION ON :—

The Constitution of Asphalt.*

By F. J. Nellensteyn.

Mr. J. E. Hackford wrote :—

Mr. Nellensteyn's paper opens up such a field of controversy that renders it impossible to do justice to the work in the time and space at our disposal.

First of all one would like to know whether by the term "Asphalt" Mr. Nellensteyn refers to naturally occurring, or to artificially made substances which would otherwise fulfil his specifications. By the text it appears that the naturally occurring bodies are meant, for asphalts artifically made by digesting oils or waxes with either sulphur or oxygen seem to be excluded, as Mr. Nellensteyn says that neither sulphur nor oxygen are essential constituents of asphalt. Before commenting further on such artificial asphalts it would be well, perhaps, to consider the definitions of asphalt. Mr. Nellensteyn refrains from defining the same, but advises us that it is obtained by the distillation of almost all the higher hydrocarbons,

* Journal, 43, p. 311, June, 1924.

and that moreover bitumens can be distinguished by the following properties :—

(1) The partial solubility in "benzene of low boiling point."

(2) On cooling it shows a marked increase in viscosity without crystallisation.

(3) "The distillate from an asphalt always displays characters very different from those of the residue, whereas in the case of other bitumens the difference is only one of degree."

"Bitumens" are defined as being substances containing carbon and hydrogen in large percentages which on distillation at atmospheric pressure yield a distillate consisting of hydrocarbons.

It is also stated that "the asphaltic substances, which constitute the essential part of asphalt are called asphaltenes," and that "the problem thus resolves itself into a study of these asphaltenes."

Clearly one must take issue on such a statement. It seems to have been Mr. Nellensteyn's intention to distinguish between oil and wax on the one hand, and the material which is not oil or wax on the other hand. Such material he calls "asphalt," but it cannot be conceded that a study of the asphaltenes alone is adequate. I have defined the material that is neither oil nor wax, as that material which is insoluble in a one per cent. solution of amyl alcohol, or a one per cent. solution of an equal mixture of ethyl ether and ethyl alcohol. In such solvents both oil and wax are soluble. The name given to the material insoluble in these solvents is termed "asphaltum," and while asphaltum contains asphaltenes, it may also contain kerotenes and diasphaltenes. That is to say the asphaltum may be insoluble or partly insoluble in carbon disulphide, in which case kerotenes are present, or it may contain a portion soluble in ethyl ether alone, in which case diasphaltenes are present. The study then is not the simple one of studying asphaltenes alone, but also of those other substances, such as diasphaltenes and kerotenes, which are clearly a part of asphaltum, but are neither oil nor wax.

Mr. Nellensteyn further defines asphalt: "Is asphalt a mixture containing only asphaltic substances? The answer is No, as distillation separates asphalt into a distillate and a residue. This might be attributed to decomposition were it not for the fact that a similar separation can be affected at 0° C. by treatment with benzine of low boiling point." This statement is very complicated and it is difficult to grasp the precise meaning. It is evident that that part of the "asphalt" soluble in benzine of low boiling point, is oil, possibly mixed with wax—and therefore not asphaltum. This can, of course, be distilled off as stated by him. Laying aside for a moment the question as to whether any part of asphaltum is

decomposed on destructive distillation we arrive at a definition of "Asphalt" as treated by Mr. Nellensteyn, viz., "Asphalt is a solution of asphaltum in oil and/or wax." I have already recorded the fact that asphaltum is decomposed on destructive distillation yielding oil and wax, with the exception of that fraction which is insoluble in pyridine and which is known as a "Kerole." The pure diasphaltenes yield the greatest percentage of distillate (55 per cent.), next the asphaltenes, next the kerotenes, and I have also shown that these bodies can all be converted into keroles by the prolonged action of a gentle heat. For example, if a sample of asphaltene be placed in a sealed tube or in an open beaker and subjected to a temperature of 100° C. for six months, it is converted into kerotenes and is then only very sparingly soluble in carbon bisulphide. In less than a year a large portion of the original asphaltenes become changed into keroles and are then insoluble in pyridine. There is little loss in weight in the transformation, small quantities of water and/or sulphuretted hydrogen being liberated, and it, therefore, appears that the transformation of diasphaltenes, *via* asphaltenes, kerotenes, kerols and keroles is a condensation process in which water and sulphuretted hydrogen are liberated. Mr. Nellensteyn also points out that condensation takes place, but I fear the condensation process is not a condensation process involving hydrocarbons alone. It is a condensation process involving –OH and –SH groups. Mr. Nellensteyn discusses the formation of asphaltum by the oxidation of the hydrocarbons present in petroleum, and it is common property that it is also formed by the thionisation of hydrocarbons. The large amount of matter given to us in the paper on the condensation of hydrocarbons instead of on the oxy or thio hydrols tempts me to paraphrase his quoted remark that "Coal contains no carbon" by the phrase that—Asphaltum contains no hydrocarbons. In view of the large amount of matter dealing with the oxidation of the oils with the subsequent formation of asphaltum, it is difficult to follow how Mr. Nellensteyn can say that neither oxygen nor sulphur can be essential constituents of "asphalts." He readily admits small quantities of oxygen in the "Asphalts," but as the oxygen is in the ether form, it is only a connecting link between radicals of high molecular weight, and, therefore, it is not likely that the percentage of the same in an asphalt will be high—indeed it can only be small.

I am in agreement with Mr. Nellensteyn as to the formation of asphaltum from oil subjected to the influence of electric discharge, but would point out that water is simultaneously formed, as also is sulphuretted hydrogen, when the oil in question contains sulphur.

REVIEWS.

STANDARD METHODS OF TESTING PETROLEUM AND ITS PRODUCTS. Institution of Petroleum Technologists, London. 6s. net.

Mr. Alexander Duckham, whose letter to the late Sir Boverton Redwood in 1917 was the *fons et origo* of the Standardization Committee of the Institution, points out in his Preface to the Report before us that it was not until May, 1921, that the appointments of the Committees were made and that the personnel included the appropriate Government Departments, the leading petroleum companies, and certain individuals of recognised authority. Considering the intricacy and magnitude of these investigations, the Committee is to be congratulated on the speedy issue of its labours.

The position was to a certain extent complicated by the previous efforts of the British Engineering Standards Association, the American Society for Testing Materials, and the American Bureau of Standards. Wherever possible, however, the results of the work of these bodies have been adopted and the Committee has worked in the closest collaboration with them.

The brochure is divided into ten sections, dealing respectively with the tests for Gasoline, White Spirit, Kerosene, Gas Oil, Lubricating Oils, Transformer and Switch Oils, Fuel Oils, Asphalts, Wax and Crude Petroleum. Not only are standard methods of testing prescribed, but also definite specifications are laid down for the apparatus employed. Thus, for example, hydrometers and thermometers are described in considerable detail, and in this connection the assistance of the National Physical Laboratory is gratefully acknowledged.

Whilst it is not intended that this issue of Standard Methods is final, and, indeed, it is obvious that periodic revision is essential in a growing industry founded on a raw material, which is as yet only partially understood, yet the Committee has done yeoman service in collecting between the covers of one manual an authoritative and agreed series of testing procedure. It redounds greatly to the credit of the Institution that it, the premier body of petroleum technologists, shall have led the way in compiling this extremely useful handbook. To the Chairman of the Committee and to Professor Brame, who saw the work through the press, great praise is due. A. E. D.

"FUEL." Resources of the Empire Series.—By G. W. Andrew. London: Ernest Benn, Ltd. 21s. net. 208+xxiv. pp.

This valuable monograph which is one of a series published under the ægis of the Federation of British Industries dealing with the principal industrial operations of the Empire may be regarded as a stocktaking of our resources, and of especial interest at the moment in view of the British Empire Exhibition at Wembley. There is a foreword by H.R.H. the Prince of Wales and a general introduction by Sir Eric Geddes.

The book itself contains sections on Coal, Lignite and Peat by Professor Louis, Fuel Oil by Arthur W. Eastlake, and Power Alcohol by Dr. Ormandy, and it will therefore be seen that the Institution of Petroleum Technologists is well represented in the production of the work.

Professor Louis' contribution is a very thorough survey of our resources in solid fuel and contains a vast amount of valuable data and tabular matter.

Of considerable interest is the table on pages 36, 37, wherein it is shown that the Empire has coal reserves of the order of two million million metre tons, whereas the world's reserves are estimated at seven million million tons.

The Imperial production during 1921 was 222,000,000 tons, the world's production during the same period being 1,118,000,000 tons. In this section is a useful summary of the carbonisation of solid fuel and a too brief account of the work of Bergius.

Mr. Eastlake in Section III. gives a mine of valuable information respecting Imperial petroleum, including shale oil. The proportion of our oil to the world's total is disappointingly small at present. India produces 1·2 per cent., Trinidad 0·3 per cent., whilst Egypt, Sarawak and Canada yield between them only 0·7 per cent. The somewhat depressing future prospect may be entirely altered if and when shales are largely exploited.

The data brought forward by the author are of extreme interest, and it is very doubtful if any previous publication has contained such a wealth of statistics.

Dr. Ormandy is the recognised expert on power alcohol, and his contribution will be read with the knowledge that the subject is treated authoritatively. He shows the great possibilities of alcohol production, apart from its well known value as a motor fuel. The annual production of sugar in the Empire is about one million tons, and the molasses from the refining of this material would yield 16 million gallons of alcohol. Power alcohol is being extensively manufactured in Australia and South Africa.

The book is well produced and reflects great credit on contributors, publishers and the Federation of British Industries. A. E. D.

VALUATION OF OIL AND GAS LANDS. By Robert Wesley Brown.

The volume under review deals in a comprehensive manner with the many variable factors which go to form the value of an oil property, as the author states in the preface: "The purpose of this book is to present in as simple a manner as is consistent with the technical nature of the subject the principles underlying the valuation of oil and gas land. The subject is intimately connected with geology, engineering economics, accounting and taxation . . . ." Such valuation is one of the hardest problems which can fall to the lot of the petroleum engineer, as although other branches of petroleum technology may be exact sciences, oil geology and the estimation of oil reserves, which after all is the vital factor, is not, and never can be, an exact science.

This subject is one which has been particularly developed in America, where taxation and the frequent sale of oil properties in all stages of development demand some form of systematic development.

Primarily the book is concerned with American problems. It must be remembered that in America development has been intense, and many of the fields show fairly consistent results, so that comparative results can be arrived at from the mass of accumulated data which are not available in less developed countries. Nevertheless, the underlying methods remain the same whether much or little information is available, and it is these underlying basic principles which form the main theme of the book.

The author commences with consideration of the meaning of "value" from various points, and then proceeds to the estimation of oil reserves both from producing wells and undeveloped territory. Many useful graphic methods are dealt with for estimating future yields of producing wells, under fairly uniform conditions such as obtain on many American fields. These methods undoubtedly give a close approximation to the ultimate yield.

In dealing with undeveloped territory, the author naturally is on much less sure ground, since the factors are unknown and must be estimated or guessed at according to information available. Two main methods are discussed—(1) the saturation method involving a calculation based on area, thickness of sand, porosity, percentage of saturation and percentage of recovery, all

of which in a new area are, as the author points out, liable to errors; (2) the acre yield method where yields per acre-foot are computed by reference to yields of similar fields. Typical acre-foot yields are given as from 200-300 barrels for many of the U.S. fields.

Petroleum prices are fully discussed and many useful curves reproduced.

Chapter VI is devoted to a consideration of costs, each of the many items contributing to the total being briefly considered, and perhaps this chapter might have with advantage been a little more detailed.

Depletion and depreciation are then considered, and in Chapter IX the actual methods applied in valuation are given, utilising all the factors as determined in the earlier part of the book.

The author then considers valuation under the Federal income tax laws, and concludes with an account of methods used for valuation of gas fields, dealing both with the saturation method as applied to gas, and the method based on decline in pressure.

This volume certainly fulfils the object with which it was written. Naturally, in such an all-embracing subject much detail has to be omitted, but as a general account of modern methods of valuation its value is undoubted, and is enhanced by the excellent way in which the material is set out.

J. R.

A Textbook of Petroleum Production Engineering. By Lester C. Uren.

Clearly printed and profusely illustrated, this volume of 20 chapters and 600 pages constitutes one of a succession of recent American books designed to instruct the student of petroleum and oilfield operations. More than passing notice is attracted to the work as it is the effort of one whose duties it is to impart the groundwork of this branch of industry to those studying the subject, and illustrates the kind of information actual experience has shown to be demanded by the American student. As explained by the author in the preface, there is still some uncertainty as to the branches into which the petroleum industry will eventually be separated. So many distinct sciences are involved that it is only during the process of education that the inclinations and adaptability of the student will become apparent, and he will naturally concentrate his energies in those channels which most appeal to his inclinations. Whether surveying, geology, engineering, chemistry or executive work eventually attracts his activities, a general knowledge of the fundamentals of oilfield work cannot fail to be of great subsequent value to all those embarking on a petroleum career.

Professor Uren introduces his subject by lightly touching upon the characteristics of petroleum and the principles governing the formation and concentration of oil and gas. He outlines and conveniently tabulates both discredited and plausible theories of origin, and he enumerates the usual surface evidences of oil. American leasing laws and customs are described in some detail, and a very good description of well log preparation is given. Reference is made to the frequent use of peg models in America where they are far more generally employed than elsewhere. It is surprising that this excellent method of depicting geological structures is not more commonly followed.

An unusually complete description of drilling methods is given covering some 110 pages, where the subject is divided into "Churn" and "Rotary" methods. The selection of material for the chapters has been made with a discrimination which indicates that the author fully appreciated his objectives. His conclusions, like those of other writers, regard the future of the rotary drill as settled, notwithstanding the various objections raised. Much useful information is given concerning the value, preparation and use

of mud fluids for drilling, and the writer emphasises the importance of attaining density without viscosity: the latter property tending to prevent the settlement of suspended sand particles such as is necessary to maintain a good mud fluid that will not cut the pumps too much. From studies made in the University of California it would appear that the best clays are the unoxidized types—grey, blue and green, rather than red, yellow and brown—of a type which will in a dry condition absorb about 30 times as much water as the less suitable varieties; indeed, up to 2·5 times their dry weight of water. It is impossible to prescribe a suitable mud for any particular field, as the circumstances are so variable. Recent writers on the subject have shown that in some cases mud becomes so "gas-cut" that plain water has had to be used instead. The extent to which the walls of wells are preserved and plastered by mud fluids is discussed, and the view is upheld that whilst the extent to which mud will enter a stratum is dependent upon the porosity of the bed, rarely does the mud extend more than an inch or two under the usual pressures employed.

Casing operations are described at some length, and the increasing difficulty of fixing precise depths by rope or casing measurements in deep wells through sag, stretch, lack of verticality, expansion, etc., are particularly emphasised. A very clear description of American fishing apparatus and methods is given accompanied by useful illustrations of typical tools.

Water exclusion methods are particularly well handled, and the varied difficulties attending cementations are discussed in a practical way. The author has apparently personally supervised a number of investigations on the subject of cements, and his comments and conclusions are, in consequence, worthy of special notice. Cement manufacture is a far too highly specialised subject for ordinary oilfield men to express opinions upon. The behaviour of different cements in the presence of mineralised, gas-saturated and perhaps oil-contaminated fluids at different temperatures within the range of deep wells is one of the most important subjects awaiting a detailed study. Ordinary operators have to rely upon some product sold in the open market, and the customary field tests are confined to some simple setting trials of samples mixed with waters with which the cement is likely to come in contact. Such superficial examinations obviously fail to reproduce the underground conditions, ans as is well known, failure after failure often results where such simple tests have proved satisfactory. On the other hand, all those associated with oilfield operations can but marvel at the number of favourable issues, considering the abuse to which the cement fluid is commonly subjected before it reaches its destination.

The author has appropriately called attention to the necessity of securing a good binding between the walls of the well and the introduced cement, otherwise there is a danger of the excluded water working its way between the two after the cement has set. Mud flush drilling is especially prone to produce a smooth and plastered surface which adversely affects a binding, and the author very properly stresses the necessity of washing the walls clear of mud before introducing cement. In especially difficult circumstances the cement fluid is forced under pressures up to 1200 lb. at the surface to ensure its penetration into slightly porous strata.

Reference is made to the increasing use of chemicals to hasten the set of cement, but the introduction of such compounds may be detrimental in other ways, and they should be used with caution. The author repeatedly refers to the value of hydraulic lime—a burnt, but unsintered, hydrated lime rock—in sealing the walls of a well. It is claimed that in contact with shales and clays, complex gelatinous silicates are formed which expand on hardening and tend to fill all pore space.

The author's hints on the use of screens are worth perusal, for whilst

admitting their general usefulness he advises discrimination in their choice and insertion if oil losses are to be avoided. An instructive account is included of shooting methods and devices. In this connection surprise can only be expressed that no safer substitute for nitro-glycerine has yet found favour. The annual death roll associated with the manufacture and use of this dangerous explosive is great, and the dangers attending its manipulation have practically limited the employment of torpedoing to the American oilfields. Other equally violent and safer compounds are known and have been successfully tested elsewhere, but little general interest has been stimulated.

Production methods are lucidly described and the principles guiding the selection of a process of extraction are outlined. The usual methods of controlling gushers and moderating flows are clearly indicated with figures.

An interesting account is given of the devices for extinguishing burning oil and gas wells. Within recent years many wild gushers have become ignited through one cause or another, and the most speedy and effective method has been by the use of snuffers and explosives, combined with steam and water jets, to cool or extinguish hot or smouldering material about the mouth of the well.

An exceptionally good description of multiple jerker line pumping methods is included. This cheap system is mainly confined to fields where the topography is flat and where wells do not exceed 2000 ft. in depth and require little attention. By a careful balancing of wells the power per well may be reduced to between 2 and 3 h.p., when a single centrally placed engine and power drives some 20 to 40 wells.

The values and limitations of air-lift pumping are outlined, but their employment for special cases has, perhaps, been somewhat under-valued. Extensive and successful use has recently been made of air in the Powell and Eldorado oilfields of Texas and Kansas. In both cases the gas was insufficient to sustain natural flow after a comparatively brief gusher period, following which, however, a high liquid level was maintained, and in the case of Powell large quantities of water complicated matters. By substituting air for pumps, the yields were frequently raised from a few hundred to a few thousand barrels daily.

Under the title of "Production Methods" the principles governing the disposition of oil in the containing strata are described, and the factors influencing extraction methods are reviewed and discussed. The author is in agreement with other investigators in considering that the recovery ratio by present practice is low. The approach to mathematical accuracy of the decline curves of wells in certain American oilfields is exemplified by selected graphs, but the author is careful to state that both artificial and natural interferences may often seriously modify their value. It has, indeed, been found impossible to apply these methods to many fields elsewhere, particularly those of Europe where the structures are complex, the spacing of wells irregular and confusing, the yields erratic, the water problem often uncertain, and nearly all wells suffer some injury at one time or another which upsets natural yield. As is well known, production in certain limestone fields, represented by parts of Mexico and Persia, is controlled, within certain maximum limits, by manipulation of a gate valve, and there is no diminution of flow. Only on the appearance of water was it necessary in Mexico to restrict a flow generally governed by the facilities for disposal of output.

The management of wells is skilfully handled in a practical way, and many useful notes are included in the paragraphs dealing with vacuum pumping and the application of gas, air or water drive to partially exhausted oil sands. Power, storage and transport problems are dealt with very

fully, and considerable space is devoted to a discussion of office methods and records.

This volume strikingly reveals throughout the personality of the writer, and represents the labour of one who has closely followed the progress of events in oildom. Much material has been collected from many sources, but oil literature has been critically scrutinised and the best and most appropriate has been liberally drawn upon and freely acknowledged. Although the contents are especially applicable to American oilfields, this in no way detracts from the value of the work, not only as a text-book for students, but a useful companion to oilfield operators.

A. B. T.

WISSENSCHAFTLICHE GRUNDLAGEN DER ERDOLVERARBEITUNG. Dr. Gurwitsch. 2nd Ed. Verlag von Julius Springer, Berlin, 1924.

Dr. Gurwitsch has confined his attention almost entirely to the chemical and physical properties of petroleum; both of the raw material and of the intermediate and finished products. The title of the book denotes its contents accurately, and those seeking for information on technical grades or for a description of manufacturing plant will find that such material has been omitted, whereas purely scientific matter has been dealt with at considerable length, recent literature having been very thoroughly searched in the compilation of scientific data.

The first part of the book is confined to the chemical and physical tests of crude oils. Descriptions of the action of halides, oxygen, ozone and other oxidising agents being given, together with the action of other chemical re-agents which have been used both experimentally and industrially in the preparation of petroleum products. A considerable amount of the information under this chapter is exceedingly useful, as, although the main portion of it is available in the literature, it is here abstracted and presented in an easily available form. Such points as the formalite reaction, polymerisation, the action of aluminium chloride, etc., are all treated very thoroughly. The physical section is also of the greatest use, and is not simply confined to a description of testing apparatus, but deals in a thoroughly scientific manner with the various physical properties. The somewhat tedious descriptions of methods of determining these properties are omitted, as such descriptions are easily available in text books of physics, and there is no necessity for them to be re-described under this section. In the second section of the book dealing with the manufacturing processes the theories of distillation and refining are dealt with at considerable length. Under this section the scientific questions appertaining to cracking are also mentioned. In the portion dealing with refining, the action of acids on paraffins, naphthenes, and aromatic and unsaturated hydrocarbons is described, and also the action of acid on asphalts and oxygen, sulphur and nitrogen compounds. The effect of the quantity of acid, method of mixing, concentration, temperature and period of time are also described under this heading, together with the action of the alkali washes and the theory of adsorption. The third section of the book deals with the properties of the products.

The book is well written and shows painstaking work in its preparation. The method of writing is such that it is necessary for the reader to have a considerable knowledge of organic chemistry to be able to make much use of the volume. To the student who has already got a good knowledge of chemistry, or to the chemist who has already had experience in dealing with petroleum products, it will prove of the greatest value. H. M.

(NOTE.—We have also received from the Shell Company of California an English translation of the 1st Edition of the above book, which was published in 1921.)

CORRECTIONS.

We have received the following correction from Mr. T. G. Madgwick:—
Jnl. 43, p. 289, 14th line from bottom. "Miocene" should read "Eocene."

In "Petroleum Geology," by T. Dewhurst, Jnl. 44, pp. 395–431, the spelling of "Columbia" should be "Colombia."